

University of Genoa

Department of Biophysical and Electronic Engineering



SIGNAL PROCESSING AND TELECOMMUNICATIONS GROUP

video and Signal Processing *for telecommunications* **(ISIP40) area**

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1 THE ISIP₄₀ AREA

The **v**ideo and **S**ignal Processing For Telecommunications (ISIP40) research team was founded in 1991 by **Prof. Carlo Regazzoni** starting from the expertise acquired in the Signal Processing and Telecommunications Group of Prof. Gianni Vernazza.

Leader of the group is still Prof. Regazzoni, Full Professor at the University of Genova, and he can rely on the help of 7 PhD students, 5 research grant co-operators and a number of external collaborators. Teaching activities allow to involve BS and MS students in the research activities of the team.

Thanks to co-operations with industries and other university groups, two new joint laboratories has been created: **Ambient Awareness Laboratory (A2Lab)** and **Cognitive Radio Laboratory (CoRLab)**, whose research activities are focused on Cognitive Surveillance and Video Surveillance and on Cognitive Radio and Wideband Communications.

The research group has a number of active projects with national and international industries and academic partners.

Moreover, the activities of the area are oriented to Image and Signal Processing, Data Fusion, Pattern Recognition and Telecommunications in the fields of:

- ◆ SECURITY
- ◆ AMBIENT INTELLIGENT
- ◆ MULTIMEDIA TELECOMMUNICATIONS NETWORKS.

This choice was due to past experiences acquired since 1988 by people working in the context of Autonomous Land Vehicles and Automatic Surveillance.

The area has developed along these years strong links with industries, government research laboratories, universities including, Ansaldo Trasporti, Ansaldo Segnalamento Ferroviario, Elsag S.p.a, FIAT CRF, Telecom, Selenia Communication, CRS Ltd. (UK), ASCOM (CH) , University of Roma (Tor Vergata), University of Firenze, University of Udine, Carnegie Mellon, Syracuse University, Aalborg University, TNO (Netherlands), Kingston University etc. Its industrial and academic contacts include teams involved in joint CEC projects (ESPRIT) and cooperation with USA/Canada Universities (Univ. of Toronto), Brown University (Providence), Northwestern University (Chicago, University of Rhode Island) and European research centers (INRIA (Sophia Antipolis), CRIF-WTC (Bruxelles), VTT Electronics (Helsinki, Finland)).

The ISIP40 area is also active within the SIIT (Integrated Intelligent Systems Technologies) of the University of Genoa.

2 MAIN RESEARCH AREAS

2.1 Multi-camera Video Sequence Processing and Understanding

A. Real Time Video Sequence Analysis for Object Recognition and Tracking

The exploitation of temporal information within a image processing system has been shown to improve the overall robustness of the results. In this sense, analysis of image sequences has been acquired an increasing importance in these last few years. The ISIP40 area has developed specific techniques for detecting, localizing and tracking multiple objects in cluttered scenes. ISIP40 research activities in this field are based on Hough transforms, Kalman filters, Particle filters, Neural Networks, Morphology, Segmentation, Adaptive Thresholding, corner extraction. Currently, some research lines have been addressed to object recognition and tracking in open environments for video-surveillance tasks. Novel algorithms have been developed for robust scene understanding using mobile and ptz cameras in order to enlarge guarded area.

B. Data Fusion and Pattern Recognition

Integration of symbolic and probabilistic techniques is the main topic of the research of ISIP40 area in the context of Data-Fusion techniques and architectures. Data-Fusion systems are developed according to a Distributed philosophy, which drives the selection of representation and inference techniques.

Graphical Models (Bayesian Networks, Multilevel Markov Random Fields, DEKFs) have been studied and find an application in the context of surveillance of underground stations.

Recognition of 2D and 3D objects in real environment (i.e., complex scenes) by meeting real-time requirements is a central task of current research in Pattern Recognition.

Our studies in this sense are based on the study of distributed recognition based on fuzzy logic, integration of Morphology and Neural Networks, Multilevel 3D object recognition, Associative memories. Application to the recognition of intruders in surveilled areas is a typical example of the use of these techniques in the context of surveillance.

C. Video Processing Techniques

Non-linear filtering techniques are studied which are based on Statistical and Mathematical Morphology, Coupled and Multilevel Markov Random Fields (MRFs), Rank-order filters, Higher-Order Spectral Analysis. Edge and region extractors are studied as segmentation techniques: in particular, specific knowledge is available in extraction of complex geometric primitives (2D and 3D), perceptual grouping and highly structured patterns. Specific knowledge is available on Non-linear feature extractor such as the Hough Transform, region-based segmentation, MRF segmentation models.

D. Cognitive Surveillance

The ISIP40 area has specific experience in the development of complete surveillance systems. In particular, knowledge is available in the context of sensor calibration techniques, scene modeling, process synchronization techniques, application dependent databases, system integration, remote information communication. Specific methods for performance evaluation of surveillance systems have been studied by the ISIP40 area.

E. Cognitive Ambient Intelligence

Ambient Intelligence can be seen as an emerging discipline resulting from the efforts in rendering technology as a transparent component of everyday life.

In literature many definitions can be found which state AmI systems as virtual entities which own three fundamental capabilities: analysis, awareness, interaction.

The aim of this research is to explore innovative methodologies finalized to equip automatic, multi-sensorial surveillance systems with features such as: increased perception and customized communications. These features appear to be functional solution to increase ambient and user security.

The augmented degree of perception in the system, is achieved by an efficient elaboration of multi-sensorial data and it appears indispensable to find dangerous situations in complex scenes with a real time behaviour.

ISIP40 competences in Ambient Intelligence and smart spaces have been expressed, for instance, in the Vicom project demonstrator; during the development of this project ISIP40 has been involved in the practical demonstration and development of Ambient Intelligence features in multi-sensor systems.

2.2 Signal Processing for Telecommunications

A. Broadband Wireless/Multiple Access

The ISIP40 area is currently studying Spread Spectrum and Code Division Multiple Access (CDMA) techniques for what concerns the following research aspects:

1. Exploitation of advanced signal processing techniques (i.e., higher order statistics based methods).
2. Use of the CDMA as a secure and noise-robust multiple access technique in applications concerning with multimedia data transmission on broadband multiservice networks (e.g. wireless LANs and cable TV networks) in the context of remote video-surveillance applications.
3. Implementation of innovative Neural Network-based multi-user detection strategies for asynchronous DS/CDMA systems in mobile and satellite communication applications.
4. Application of Multicarrier CDMA (MC-CDMA) multiple access techniques to variable-bit-rate satellite multimedia communications.

B. Cognitive Radio Applications

Cognitive radio is a paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behaviour and network state.

Although cognitive radio was initially thought of as a software-defined radio extension (Full Cognitive Radio), most of the research work is currently focusing on Spectrum Sensing Cognitive Radio, particularly in the TV bands. The essential problem of Spectrum Sensing Cognitive Radio is in designing high quality spectrum sensing devices and algorithms for exchanging spectrum sensing data between nodes. It has been shown that a simple energy detector cannot guarantee the accurate detection of signal presence, calling for more sophisticated spectrum sensing techniques and requiring information about spectrum sensing to be exchanged between nodes regularly. Increasing the number of cooperating sensing nodes decreases the probability of false detection.

Filling free radio frequency bands adaptively (OFDM) seems to be the ideal approach. In fact, Timo A. Weiss and Friedrich K. Jondral of the University

of Karlsruhe proposed a Spectrum Pooling system in which free bands sensed by nodes were immediately filled by OFDM subbands. Applications of Spectrum Sensing Cognitive Radio include emergency networks and WLAN higher throughput and transmission distance extensions.

C. MIMO Wireless Communications

In wireless communications, multiple-input and multiple-output (MIMO), is the use of multiple antennas at both the transmitter and receiver in order to improve communication performances.

MIMO technology has attracted attention in wireless communications, since it allows significant increases in data throughput and coverage range without needing additional bandwidth or transmit power. It achieves this by higher spectral efficiency and diversity. Because of these benefits, MIMO is a current topic of international research.

MIMO can be sub-divided into three main categories: precoding, spatial multiplexing, and diversity coding.

In particular, spatial multiplexing techniques makes the receivers very complex, and therefore it is typically combined with Orthogonal Frequency-Division Multiplexing (OFDM) or with Orthogonal Frequency Division Multiple Access (OFDMA) modulation, where the problems created by multi-path channel are handled efficiently. The IEEE 802.16e standard incorporates MIMO-OFDMA. The IEEE 802.11n standard, which is expected to be finalized soon, recommends MIMO-OFDM.

D. Signal processing for localization

The ISIP40 area is currently working on the satellite based navigation topic for what concerns the following research aspects:

1. Exploitation of advanced signal processing techniques for synchronization and code tracking modules.
2. Implementation of non linear filtering for noise reduction in jammed environment.
3. Implementation of innovative Neural Network-based strategies for tracking modules.
 1. Integration of navigation systems (GALILEO) and 3G mobile communication systems (UMTS).

The ISIP40 area is further interested at investigating the possible way of integration between GPS equipped on a PDA and mobile cameras.

The data fusion between the modules allows one to achieve better user position estimation and tracking performances also when an occlusion occurs.

MAIN RECENT PUBLICATIONS ('03'-'08')

- G.L.Foresti,C.S.Regazzoni, P.Varshney, "Multisensor Surveillance Systems, The Fusion Perspective", Kluwer academic Publisher, Boston, MA, USA,2003.
- L. Marchesotti, S. Piva and C. Regazzoni "Structured Context Analysis Techniques in Biologically Inspired Ambient Intelligence Systems", IEEE Trans. on Systems, Man and Cybernetics, Part A, Special Issue on Ambient Intelligence, N.1, Vol.35, January 2005, pp. 106-120 (2005 IEEE)
- L. Marchesotti, C.S. Regazzoni, C. Bonamico, F. Lavagetto, "Video Processing and Understanding Tools for Augmented Multisensor Perception and Mobile User Interaction in Smart Spaces", International Journal of Image and Graphics, Vol. 5, No. 3 (2005) pp. 679-698
- G. Scotti, L. Marcenaro, C. Coelho, F. Selvaggi and C.S. Regazzoni, "Dual camera intelligent sensor for high definition 360 degrees surveillance," IEE Proceedings on Vision, Image and Signal Processing, Volume 152, Issue 2, 8 April 2005 Page(s):250 - 257.
- F. Parodi, M. Musso, A.F. Cattoni, C.S. Regazzoni, A hierarchical Neural Network-based receiver for GNSS systems, European Navigation Conference – Global Navigation Satellite Systems, May 7-10, 2006, Manchester, United Kingdom
- M. Gandetto, A.F. Cattoni, C.S. Regazzoni, A Distributed Wireless Sensor Network for Radio Scene Analysis, International Journal of Distributed Sensor Networks, Taylor & Francis Publishing, 2006.
- M. Gandetto and C.S. Regazzoni, "Spectrum Sensing: A Distributed Approach for Cognitive Terminals", IEEE Journal on Selected Areas in Communications, Vol. 25, No. 3, April 2007.
- M. Asadi and C.S. Regazzoni, "A Comparison of Different Approaches to Nonlinear Shift Estimation for Object Tracking", IEEE ICIP, Texas, USA, September 2007.
- A. Dore, M. Musso, and C.S. Regazzoni, "MAP Particle Selection in Shape-Based Object Tracking" IEEE International Conference on Image Processing, ICIP 2007, San Antonio, TX, USA, 16-19 September 2007.

- C.S. Regazzoni M. Gandetto, "Spectrum sensing: a distributed approach for cognitive terminals," IEEE Journal on Selected Areas in Communications - Special Issue on Adaptive, Spectrum Agile and Cognitive Wireless Networks, Vol. 25, No. 3, April 2007.
- M. Asadi, and C.S. Regazzoni, "Tracking Using Continuous Shape Model Learning in the Presence of Occlusion", EURASIP Journal on Advances in Signal Processing, Special Issue on Track Before Detect Algorithms [in press – draft version available on line]

3 Editorial Activities and Conference Organisation

AMONG THE EDITORIAL ACTIVITIES OF THE ISIP40 AREA, THE FOLLOWING BOOK CONTRIBUTIONS AND GUEST EDITORING ACTIVITIES MUST BE MENTIONED:

- **VIDEO-BASED SURVEILLANCE SYSTEMS COMPUTER VISION AND DISTRIBUTED PROCESSING** edited by Paolo Remagnino (Kingston University, London), Graeme A.Jones (Kingston University, London), Nikos Paragios (Siemens Corporate Research).
- **Advanced Video-Based Surveillance Systems** edited by Carlo S. Regazzoni (University of Genova, Italy), Gianni Fabri (Italtel S.P.A, Milano, Italy), Gianni Vernazza (University of Cagliari, Sardinia, Italy)
- **Multimedia Video-Based Surveillance Systems Requirements, Issues and Solutions** edited by Gian Luca Foresti (Computer Science Dept., University of Udine, Genoa, Italy), Petri Mähönen (VTT, Technical Research Center of Finland and University of Oulu, Finland), Carlo S. Regazzoni (University of Genova,
- **Multisensor Surveillance Systems** edited by Carlo S. Regazzoni (University of Genova, Italy), Gian Luca Foresti (Computer Science Dept., University of Udine, Genoa, Italy), Pramod K. Varshney (Dept. Electrical Engineering and Computer Science, Smith College, Syracuse University)
- Guest editing Proceedings of the IEEE *Special Issue on THIRD GENERATION SURVEILLANCE SYSTEMS*.
- Guest editing with Tap Yap-Peng (Nanyang Technological University) *Special Issue on Audio-Visual Signal Processing for Intelligent Security Systems*, 2006.
- Guest editing with Kostas Plataniotis (Univ. Of Toronto, Canada) of *Special Issue of IEEE Signal Processing Magazine on Surveillance Networks*, 2005.
- Guest editing with Aishy Amer (Columbia University) of *Special Issue of Real-Time Imaging Journal “Video Object Processing for Surveillance Applications”* ,2004
- Guest editing with Gianluca Foresti (Univ. of Udine) *Special Issue of Real-Time Imaging Journal*, on “Video Processing and Communications in Real-Time Video-Based Surveillance”, June 2001.

- Guest editing with Gianluca Foresti (Univ. of Udine) and Ramesh Visvanathan (Siemens Princeton, USA) of Special Issue on the Proceedings of the IEEE about “Video Communications, Processing and Understanding for Third Generation Surveillance Systems” (2001).
- The ISIP40 area collaborated actively in the organization of IEEE ICIP05 conference that was hold in Genoa in September 2005. The IEEE International Conference on Image Processing (ICIP) is widely regarded as the most prestigious forum for the presentation of technological advances and research results in the fields of theoretical, experimental, and applied image and video processing. The ICIP conference is an excellent chance to discuss and share with colleagues the latest research results in the image processing field. Besides it allows a high standard improvement and advancement of any knowledge related to image and video imaging technologies and surely provides with good opportunities of exchange and contact
- The ISIP40 group is also collaborating for the organization of AVVS09 conference. The IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS) has a tradition of participation from the worlds of research, industry, and relevant government agencies. AVSS09 welcomes contributions in traditional disciplines such as tracking, activity monitoring, biometrics, object detection and recognition, reconnaissance, signal surveillance/processing, applications/systems/tools, sensor networks/fusion/infrastructure, performance evaluation, non-visual imaging, 3D surveillance, behaviour analysis, theoretical Foundations, data mining, privacy issues.

4 STAFF MEMBERS OF THE ISIP40 AREA



Carlo Regazzoni
Head Professor



Carlo Regazzoni He received the “laurea” degree in Electronic Engineering and the Ph.D. in Telecommunications and Signal Processing from the University of Genoa, in 1987 and 1992, respectively. In 1993 he has been visiting researcher at the Department of Electrical and Computer Engineering of the University of Toronto. He has been Associate Professor and Assistant Professor in Telecommunications at Department of Biophysical and Electronic Engineering (DIBE), University of Genoa, since 2000 and 1995, respectively. He is Full Professor at DIBE since 2006. Since 1997 he has been visiting Professor on Pattern Recognition at Master course in Information Technology at COGEFO, Milan, Italy and visiting Professor in Telecommunications Systems at University of Trento, Italy, respectively. Since 1990 he is responsible of the vIdeo & SIgnal Processing for telecommunications Group (ISIP40) area of the Signal Processing & Telecommunications Group (SP&T) at DIBE.



Francesca Grasso
Secretary



Francesca Grasso received the Laurea (M. Sc.) cum laude in Modern Literatures and Civilizations from University of Genoa in 2007. Currently she is ISIP40 group secretary.



Andrea Cattoni
CoRLab



Andrea Cattoni (post Ph.D.) was born in Genoa (Italy) in 1979. He obtained the Laurea degree in Telecommunications Engineering in June 2004 at the University of Genoa, Italy, with a thesis concerning feature reduction algorithms for remote sensed hyperspectral images. From October 2004 he cooperates with ISIP40 group, working on Cognitive Radio techniques and location systems. From 2005 he has been a Ph.D. student in Information and Communication Science and Technology – Space Sciences and Engineering, his research topics are: Distributed Cognitive Radio technologies and Advanced Positioning Systems. In 2008 he received the Ph.D. from the University of Genoa. He is author and co-author of more than twenty papers presented at refereed international conferences, an international journal and a book chapter.



Luca Bixio
CoRLab



Luca Bixio received the “laurea” degree in Telecommunications Engineering at University of Genoa, Italy, in March 2006, with a thesis concerning signal propagation in urban environment. From March 2007 he cooperates with Cognitive Radio Laboratory, working on synchronization techniques for OFDMA system in high mobility environment and Cognitive Radio. From January 2008 he is a PhD student in Information and Communication Science and Technology - Space Sciences and Engineering at the University of Genoa. His research topics are: Distributed Cognitive Radio techniques and WiMAX technology. He is author and co-author of some papers presented at international conferences.



Hany Sallam
CoRLab



Hany Sallam received the Laurea (B. Sc.) with honour degree in Computer Science and engineering from Menoufia University, Egypt in 1995 and Laurea (M. Sc.) in Computer Science and Engineering from Menofia University, Egypt in 2002. From 2005 he is a Ph.D student at the Computer Engineering and System department of Cairo University, Egypt and in 2007 joined ISIP40 group as a visiting student.



Majid Asadi
A2Lab



Majid Asadi was born in Iran in 1979. He received his BS in Computer Engineering from University of Isfahan in 2001 and his Master degree from Sharif University of Technology in 2004. After graduation, he served as researcher at the Advanced Information and Communication Research Center (AICTC) of Sharif University for one year. Before starting the PhD Program, he had a three month research grant at the University of Genoa. Currently he is working toward his PhD degree as a research fellow at the Group of Video and Signal Processing for Telecommunication at the Department of Biophysical and Electronic Engineering, University of Genoa.



Alessio Dore
A2Lab



Alessio Dore obtained his "Laurea" degree (M.Sc.) in Telecommunications Engineering in 2006 discussing a thesis on tracking and performance evaluation of tracking system which has been partially developed at Kingston University - London under the guidance of Dr. James Orwell. From March 2006 to December 2006 he worked as a collaborator at ISIP40 lab (University of Genova). Since January 2007 he is a Ph.D. student in University of Genova - Department of Biophysical and Electronic Engineering (DIBE). He is author and co-author of some papers presented at international conferences.



Stefano Maludrottu
A2Lab



Stefano Maludrottu attained a M.Sc. in Informatic Engineering in November 2006 with a thesis titled "Tracking methods for moving objects in mobile robotics". Before starting the PhD Program, he had a nine month research grant at the University of Genoa. Currently he is working toward his PhD degree as a research fellow at the Group of Video and Signal Processing for Telecommunication at the Department of Biophysical and Electronic Engineering, University of Genoa. His main activities concern applications of neurogenetic algorithms for image processing tasks.



Andrea Beoldo
A2Lab



Andrea Beoldo received his “Laurea” in Telecommunications Engineering from University of Genoa in 2005. Currently he is working as a research grant at the Group of Video and Signal Processing for Telecommunication at the Department of Biophysical and Electronic Engineering, University of Genoa. His research field concerns with novel tracking algorithms and applications for driver assistance intelligent systems.



Matteo Pinasco
A2Lab



Matteo Pinasco received his “Laurea” degree in Telecommunications Engineering from University of Genoa in March 2007. In May 2007 he was involved in a joint collaboration between the Department of Biophysical and Electronic Engineering and Ansaldo Signal (private company). Since January 2008 he is working toward his PhD degree as a research fellow at the Group of Video and Signal Processing for Telecommunication at the Department of Biophysical and Electronic Engineering, University of Genoa in collaboration with Ansaldo. His main activities concern applications of multi-camera systems for surveillance and ambient intelligence systems.



Lorenzo Ciardelli
A2Lab



Lorenzo Ciardelli received his BS in Telecommunications Engineering from University of Pisa in 2003 and his Master degree from University of Pisa in 2006. In March 2007 he had a three month collaboration at the University of Genoa. Since June 2007 he is working as a research grant at the Group of Video and Signal Processing for Telecommunication at the Department of Biophysical and Electronic Engineering, University of Genoa. He is currently developing methods and tools for ambient intelligence applications.



Giuseppe Gioco
A2Lab



Giuseppe Gioco received the Laurea (M. Sc.) in Electronic Engineering from University of Genoa in 2007. After an experience as software developer for a private company, since January 2008 he is working as a research grant at the Group of Video and Signal Processing for Telecommunication at the Department of Biophysical and Electronic Engineering, University of Genoa. His research is focused on video surveillance systems and applications.



Giacomo Oliveri
CoRLab



Giacomo Oliveri received the "master degree" in Telecommunications Engineering at University of Genoa, Italy, in 2005. He is currently a PhD student in Information and Communication Science and Technology at the University of Genoa, Italy. His researches are mainly focused on cognitive antennas, innovative materials and numerical methods for electromagnetic problems.



Marina Ottonello
CoRLab



Marina Ottonello received the "master degree" in Telecommunications Engineering at University of Genoa, Italy, in 2006. She is currently a PhD student in Information and Communication Science and Technology at the University of Genoa, Italy. Her researches are mainly focused on cognitive radio and smart antennas.

5 ISIP40 SPIN-OFF



TechnoAware is a spin-off composed by former students of ISIP40 that is still in close contact with the group

TechnoAware designs and develops data and image processing intelligent systems for automatic video surveillance and context aware computing.

Thanks to the innovative technologies and to the technical-scientific competences of its team, TechnoAware systems are able to acquire and elaborate images and multi-sensorial data coming from an environment, to comprehend automatically and in real time the contents and the events happening therein. Founded in 2003, TechnoAware rises by the will to transfer to market the technologies developed among the research laboratories of the Department of Biophysical and Electronic Engineering of Genoa University, with which maintains a strong partnership towards the continuous exploration and evolution of innovative solutions and methodologies. The goal TechnoAware aims is to offer technologically advanced solutions among integrated systems for ambient intelligence. TechnoAware offers its products and services both to end-users (public, private,...) and businesses (installers, producers, distributors, consulting companies, ..).

TechnoAware designs and develops integrated intelligent systems able to:

- **capture and elaborate in real time multisensory data from an environment**
- **detect, classify, locate and track subjects of interest**
- **detect and signal anomalous events of interest**
- **allow the environment interaction with itself and with its users going on what it detects**

Company's strengths:

- **Proprietary technologies**
 - Flexible and modular solutions
- **Advanced technical-scientific expertise**
 - High quality products and services
- **Continuous support for research and technology innovation**
 - Technologically advanced solutions

<http://www.technoaware.com/>