The research envisaged covers a broad spectrum of issues related to Computer Vision, Pattern Recognition, and Image Processing, and participates in a variety of applied projects, where results and know-how from those programs are exploited. The research group is involved in organizing the biennal Workshop on Fuzzy Logic and Applications (WILF) and a series of special issues in international scientific journals to cover the research topics. The mainstreams of the research are:

- Pattern Recognition. Research in this field is mainly focused on the probabilistic and fuzzy models for pattern recognition, because of their interesting theoretical properties and their wide applicability in (not only) computer vision tasks. Our interest is mainly in investigating Neural Networks, Markov Random Fields, Neuro-Fuzzy and Kernel Methods. We are interested both in methodological, e.g. learning and model selection, and applicative issues, as shape classification, event detection and classification and clustering, tracking, and video surveillance. Our research is also oriented on very promising techniques for dealing with structured data.

- Computer Vision. The research is naturally focused on image analysis and understanding aspects in the large, which are at the basis of all advanced processing. Specific expertise on multiresolution, object recognition, soft computing in image analysis, attentive vision mechanisms with applications to video surveillance, medical imaging, multimedia data treatment.

Specifically:

1) Intelligent spatio-temporal signal processing

The efficient management of spatiotemporal data has gained much interest during the past few years, mainly due to the rapid advancement in telecommunications which facilitates the collection of large data sets of such information. Management and analysis of moving object trajectories are challenging due to the vast amount of collected data and novel types of spatiotemporal queries. In many applications, the movements obey periodic patterns, i.e., the objects follow the same routes (approximately) over regular time intervals. Objects that follow approximate periodic patterns include transportation vehicles (buses, boats, airplanes, trains, etc.), animals, mobile phone users, etc. The problem of discovering periodic patterns from historical object movements is very challenging. Usually, the patterns are not explicitly specified, but have to be discovered from the data. The approximate nature of patterns in the spatiotemporal domain increases the complexity of the mining tasks. The classes of techniques that we are proposing to investigate are:

- Clustering, that is discovery of groups of "similar" trajectories. As an example, the cluster of trajectories they can bring to light the presence of paths not adequately covered from the public transit service.

- Frequent pattern, that is the discovery of frequent paths. These information could be useful for the city planning, as an example, evidencing frequently covered paths followed by vehicles, that could be the result of planning of the devoid traffic.

- Classification, that is the discovery of behavior rules, aiming to explain the behavior of the running customers and to foretell that one of the future customers. An application could be the pre-allocation of resources. From the methodological standpoint, the research activity investigates machine learning approaches and specifically neuro-fuzzy models.

2) Structured pattern recognition

In machine learning, very powerful and efficient methods have been proposed when data are represented by flat and fixed-width real vectors, even when heavily corrupted by noise. Neural networks, support vector machines and statistical methods are well known and widely used techniques. All of them share many successful stories in real-life problems, a well established theoretical background, and many journals and conferences devoted to explore possible refinements and applications. Unfortunately, in many relevant applications, data are not naturally expressed in terms of flat vectors. More expressive data structures, as trees or graphs, often nicely capture essential properties of the problem at hand, simplifying its mathematical representation and paving the way for its solution. Also, the features characterizing the input vectors are quantitative, i.e. numerical in nature, but features having imprecise or incomplete specification are usually either ignored or discarded from the design and test sets. The concept of Zadeh's fuzzy set theory can be introduced into the machine learning process to cope with impreciseness arising from various sources. For example, it may become convenient to use linguistic variables and hedges (small, medium, high, very, more and less, etc.) in order to describe the feature information. Again, uncertainty in classification may arise from the overlapping nature of classes; realistically speaking, the feature vector characterizing a specific pattern can and should be allowed to have degrees of membership in more than one class. The research activity concerns the design of neuro-fuzzy and kernels models for processing structured data. The studies relating the insertion of fuzzy rule-based domain knowledge and hence the fuzzy automaton state transitions into neural or kernel models should provide two benefits: (i) improving generalization to new instances and (ii) simplifying learning. The applications include 2D e 3D object recognition.

3) Soft computing for image analysis

The rise of several major seminal theories proposed in early 60's including fuzzy logic, genetic algorithms, evolutionary computation, neural networks and their combination (the soft-computing paradigm in brief) allows to incorporate imprecision and incomplete information, and to model very complex systems, making them a useful tool in many scientific areas. These new methods may become more effective and powerful in real-world applications and can offer viable and effective solutions to some of the most difficult problems in image and pattern analysis. The research activity concerns the design of a computational model that takes advantage of the notion of rough fuzzy sets and learning to realize a system capable to efficiently cluster data coming from computer vision tasks. The hybrid notion of rough fuzzy sets comes from the combination of two models of uncertainty like vagueness by handling rough sets (Pawlak, 1985) and coarseness by handling fuzzy sets (Zadeh, 1975). Rough sets embody the idea of indiscernibility between objects in a set, while fuzzy sets model the ill-definition of the boundary of a sub-class of this set. Marrying both notions lead to consider, as instance, approximation of sets by means of similarity relations or fuzzy partitions. The proposed

multi-scale mechanism, based on a model of rough fuzzy sets is adopted to spread out local into more global information. The local features extracted by the consecutive layers are combined in the output layer in order to cluster the output neurons by minimizing the fuzziness of the output layer. This constitutes a fast algorithm for computing scale spaces, and apply them to image processing. We report results for region-based image segmentation and edge detection by minimizing measures of fuzziness, while texture segmentation is realized by optimizing parabolic-evolutive partial differential equations with edge preserving smoothing properties. An efficient block coding scheme is also designed upon the rough-fuzzy model, together with the adoption of machine learning techniques for vector quantization, as compared against Fuzzy Transform and Fuzzy Relational techniques. The rough-fuzzy synergy is also adopted to better represent the uncertainty in color image representation and histogram based indexing mechanisms.

Activities concern several aspects of digital film restoration, including the analysis of issues related to the problem, ranging from the kind of different defects, to their causes, and to methods and algorithms for their removal. Particular attention is given to some specific types of defects that can affect digital image sequences and to methodologies adopted for their management, devising new machine learning based algorithms and methodologies for their removal. Defects taken into consideration include dust and dirt and linear scratches. We have proposed methods for automatic removal of linear scratches in digital image sequences, based on the idea of adopting an image model as simple as possible, evaluate the displacement of such model from the real model, and correct scratch removal through the addition of the computed displacement. Moreover, we devised a method for the detection and the removal of linear blue scratches that affect also modern color movies, based on specific characteristics of such kind of defect. We also proposed a new methodology for the solution of classes of problems related to digital film restoration that is well suited for implementation into high-performance parallel and distributed computing environments. The basic idea is to adopt several well settled algorithms for the class of problems at hand, and to combine obtained results through the adoption of suitable image fusion techniques, with the aim of taking advantage of adopted algorithms potentialities and at the same time reducing their disadvantages. Finally, for dust and blotch removal, a novel approach was envisaged, based on viewing the problem as one of separating overlapping images, and then reformulating it as a Blind Separation problem, approached through Independent Component Analysis techniques.

4) Videosurveillance

The activity concerns the analysis, design and implementation of machine learning methods for the detection, tracking and real-time recognition of objects in motion sequences, also in mobile environments. Concerning real-time support, extensions of a video surveillance system have been proposed to make possible to guarantee speedup very close to the ideal, while improving the accuracy of the results detection. The extensions include the design of parallelization techniques at instruction-level, by SSE2, of the main computational cores and the real-time support to the operating systems to reduce jittering in video mobile transmission. Detection is dealt by proposing an approach based on self organization through artificial neural networks, widely applied in human image processing systems and more generally in cognitive science. The approach, adopted as basis to model either background and foreground, can handle

scenes containing moving backgrounds, camouflage and gradual illumination variations, can include into the background model shadows cast by moving objects, and achieves robust detection for different types of videos taken with stationary cameras. Moreover, for object tracking we propose an Artificial Intelligence approach to improve correct estimates, that suitably combines Particle filtering and a matching model belonging to the class of Multiple Hypothesis Testing.