Il Progetto SIMBAD

Beyond Features:

Similarity-Based Pattern Analysis and Recognition

Marcello Pelillo **Andrea Torsello**

Computer Vision and Pattern Recognition Group

Dipartimento di Informatica

Università Ca' Foscari, Venezia

What is SIMBAD

- SIMBAD is an FP7 FET-Open (STREP) research project funded by the European Commission
- The VII Framework Programme (2007 – 2013) is the main tool for the implementation of the research policies of the European Commission
- The programme has a total budget of over € 50 billion
- Grants are determined on the basis of calls for proposals and a peer review process, which are highly competitive

What is FET Open?

- The purpose of FET open is to enable a range of ideas for future and emerging technologies to be explored and realised.
- The scheme is open to the widest possible spectrum of research opportunities that relate to Information Society Technologies.
  - The realisation of bold ideas that would involve high risks
  - High quality longer term research with sound objectives

FET-Open call Batch 1 overview

STREPs	No. Proposals
– Submitted short STREP	98
– Above threshold short STREP	25
– Submitted full STREP	23
– Above threshold full STREP	16
– Retained for funding	9

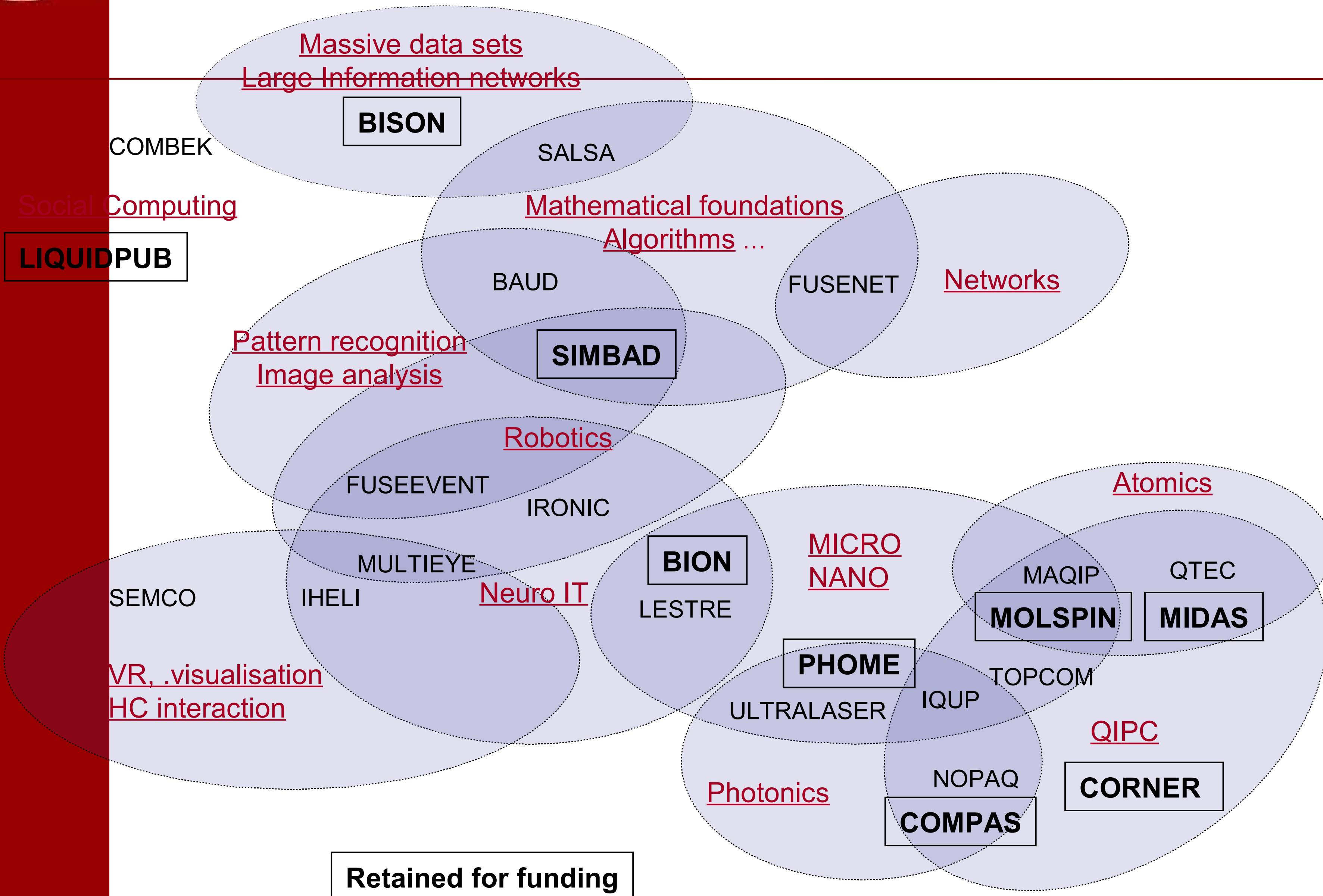
1/4

2/5

1/10

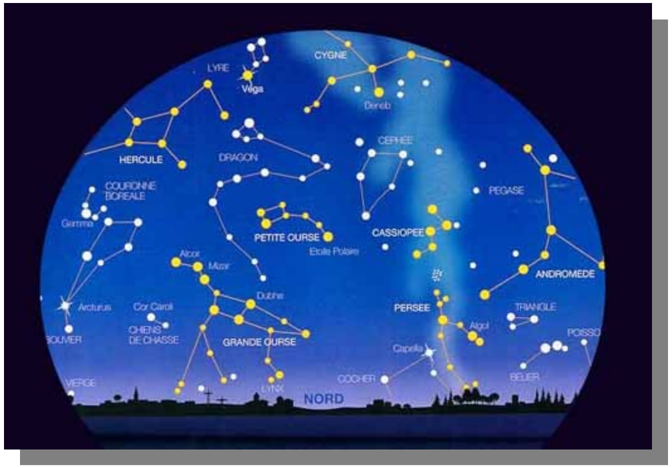
The Partners

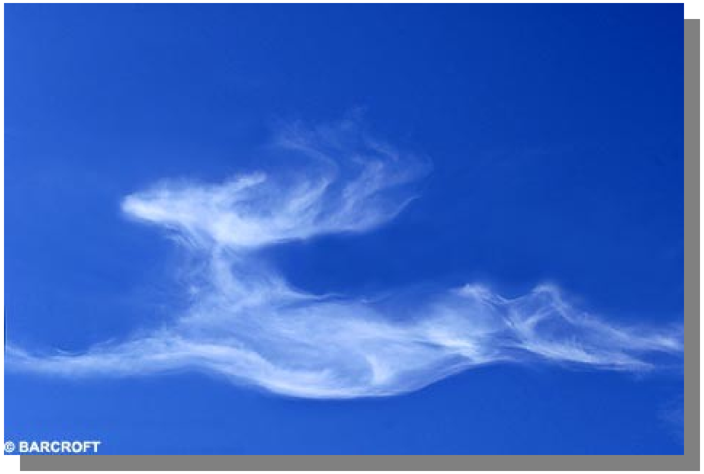
1. Università Ca' Foscari di Venezia (IT)
2. University of York (UK)
3. Technische Universiteit Delft (NL)
4. Insituto Superior Técnico (PL)
5. Università degli Studi di Verona (IT)
6. Eidgenössische Technische Hochschule Zürich (CH)

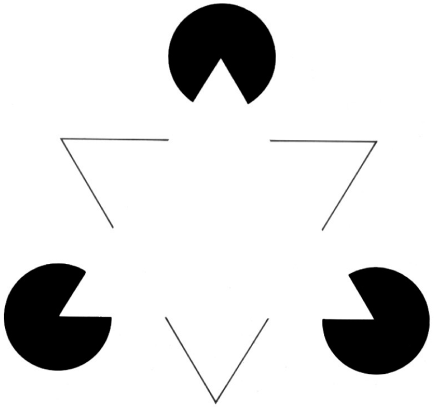

Massive data sets
Large Information networks
BISON
COMBEK
SALSA
Social Computing
LIQUIDPUB
Mathematical foundations
Algorithms …
BAUD
FUSENET
Networks
Pattern recognition
Image analysis
SIMBAD
Robotics
FUSEEVENT
IRONIC
Atomics
MICRO
NANO
BION
MULTIEYE
SEMCO
IHELI
Neuro IT
LESTRE
MAQIP
QTEC
MOLSPIN
MIDAS
VR, .visualisation
HC interaction
PHOME
TOPCOM
ULTRALASER
IQUP
QIPC
NOPAQ
CORNER
Photonics
COMPAS
Retained for funding

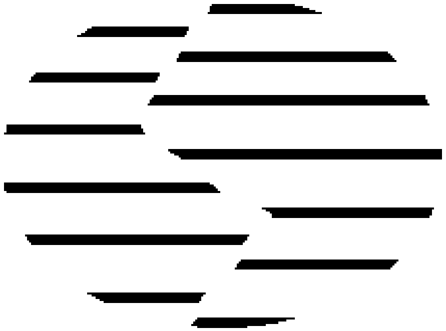
The Instinct for Patterns

We see patterns everywhere… even where there are no patterns!









Pattern Recognition and Machine Learning

- The field of pattern recognition is concerned with the (automatic) discovery of regularities in data
- Endow artificial systems with the ability to improve their own performance in the light of new external stimuli. and cope with novel or indeterminate situations.
- Traditional pattern recognition techniques are centered on the notion of “feature”
- Each object is described in terms of a vector of numerical attributes and is therefore mapped to a point in a Euclidean (geometric) vector space

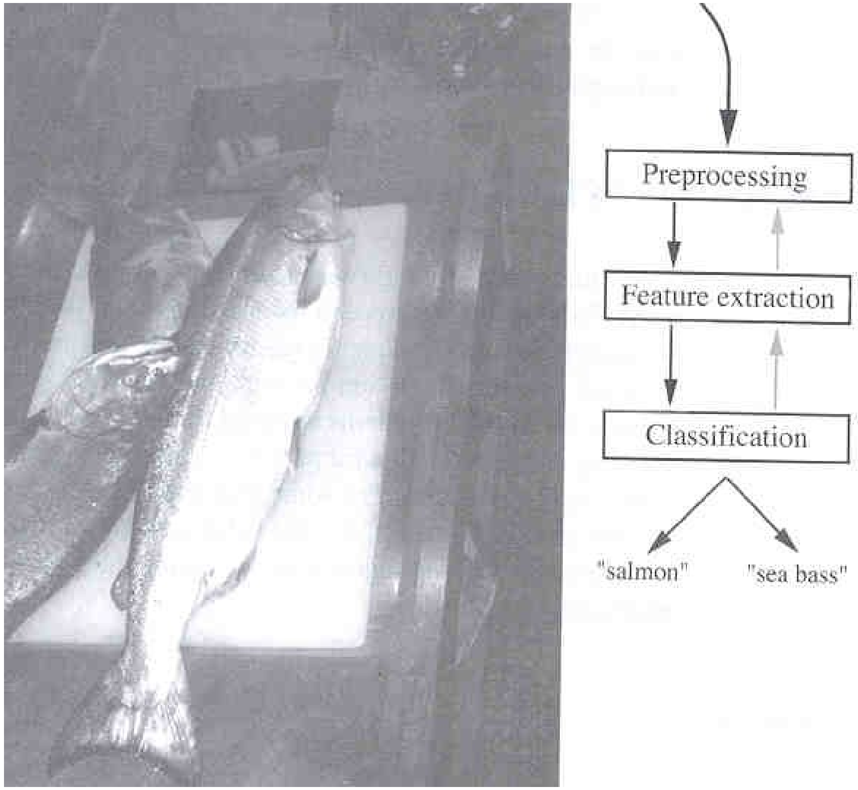
Example of Feature-Based Pattern Recognition

Classification of fish into two classes:

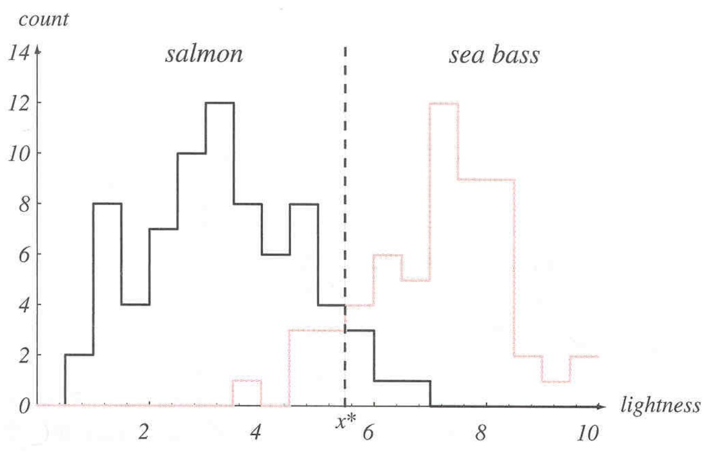
Class #1: *Salmon*
Class #2: *Sea Bass*

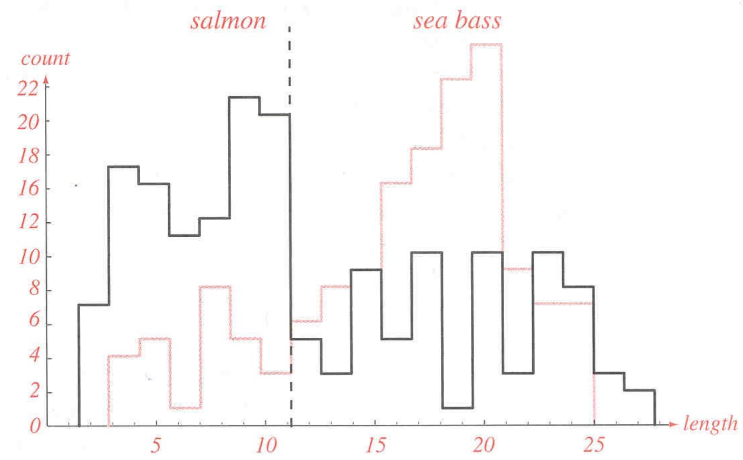
Using 2 features:

Feature #1: *Lightness*
Feature #2: *Length*

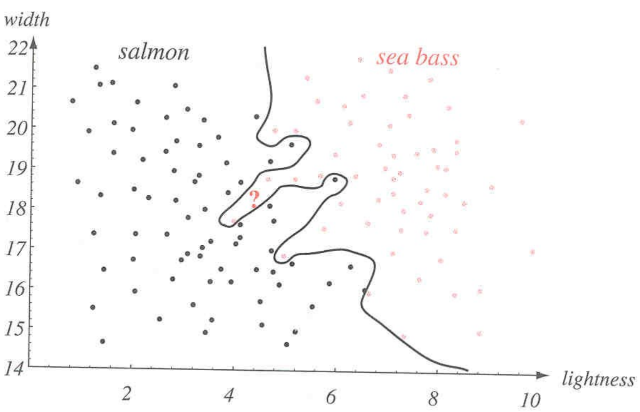


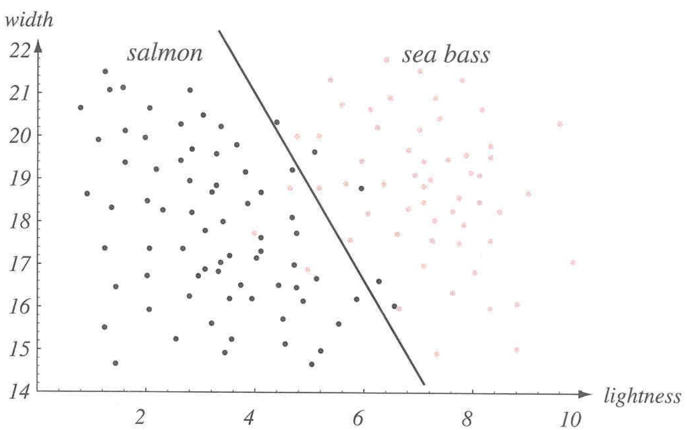
Features and Distributions

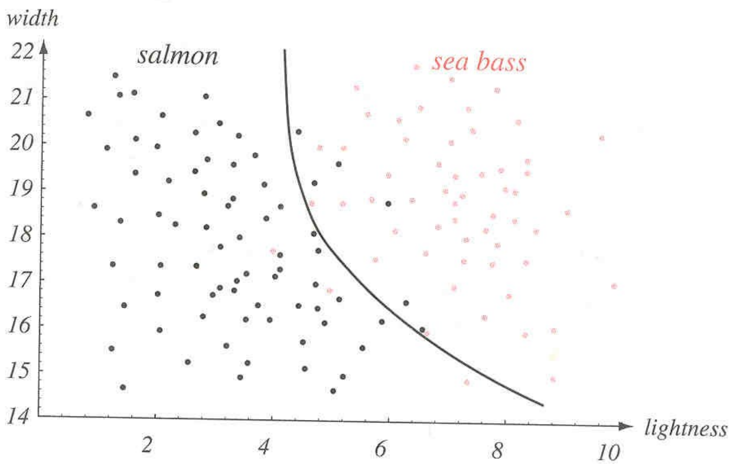




Decision Boundaries







Applicability of Features

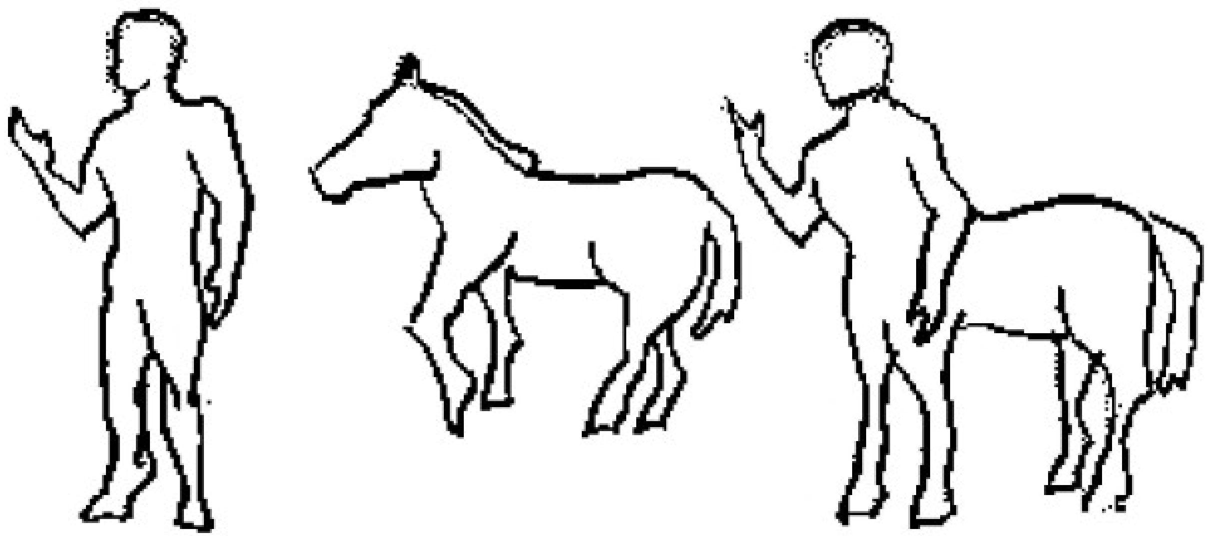
- There are numerous application domains where
  - It is not possible to find satisfactory features
  - they are inefficient for learning purposes.
- This is typically the case when
  - experts cannot define features in a straightforward way
  - data are high dimensional
  - features consist of both numerical and categorical variables
  - in the presence of missing or inhomogeneous data
  - objects are described in terms of structural properties, such as parts and relations between parts, as is the case in shape recognition (Biederman, 1987).

Problems with featureless representations

- Departing from vector-space representations one is confronted with the challenging problem of dealing with (dis)similarities that do not necessarily possess the Euclidean behavior or not even obey the requirements of a metric.
- The lack of the Euclidean and/or metric properties undermines the very foundations of traditional pattern recognition theories and algorithms

Occurrence of non-metric similarities

- Non-Euclidean or non-metric (dis)similarity measures are naturally derived when images, shapes or sequences are aligned in a template matching process.
- The violation of the triangle inequality is often not an artifact of poor choice of features or algorithms, and it is inherent in the problem of robust matching when different parts of objects (shapes) are matched to different images.
- The same argument may hold for any type of local alignments. Corrections or simplifications may therefore destroy essential information.



Themes

- Researchers are becoming increasingly aware of the importance of similarity information *per se*.
- This project aims at bringing to full maturation a paradigm shift that is currently just emerging within the pattern recognition and machine learning domains
- The whole project will revolve around two main themes
  - How can one *obtain* suitable similarity information from object representations that are more powerful than, or simply different from, the vectorial?
  - How can one *use* similarity information in order to perform learning and classification tasks?

Tasks

WP2. Deriving similarities for non-vectorial data

WP3. Foundations of non-(geo)metric similarities

WP4. Imposing geometricity on non-geometric similarities

WP5. Learning with non-(geo)metric similarities

WP6. Analysis of tissue micro-array images of renal cell carcinoma

WP7. Analysis of brain magnetic resonance scans for the diagnosis of mental illness

The Role of the Venice Unit

1)Develop a game-theoretic framework based on a formalization of the competition between the hypotheses of class membership.

2)Develop a probability space for structural data.

Game theoretic framework

- A classical strategy to attack pattern recognition problems consists of formulating them in terms of optimization problems.
- In many real-world situations, however, the complexity of the problem at hand is such that no single (global) objective function would satisfactorily capture its intricacies.
- Examples include:
  - using asymmetric compatibilities in (continuous) consistency labeling problems (Hummel & Zucker, 1983)
  - integrating region- and gradient-based methods in image segmentation tasks (Chakraborty & Duncan, 1999)
  - clustering with asymmetric affinities (Torsello, Rota Bulò & Pelillo, 2006)

Game Theory

- Game theory was developed precisely to overcome the limitations of single-objective optimization (J. von Neumann, J. Nash).
- It aims at modeling complex situations where players make decisions in an attempt to maximize their own (mutually conflicting) returns.
- Nowadays, game theory is a well-established field on its own and offers a rich arsenal of powerful concepts and algorithms.
- Note: in the case of a particular class of games (i.e., doubly-symmetric games) game-theoretic criteria reduce to optimality criteria.

Objective

- Our goal is to introduce a novel perspective for (similarity-based) pattern analysis and recognition which goes beyond the traditional view that the decisions taken by a decision-maker should be optimal, according to some single, global criterion.
- According to this perspective, the focus will shift from optima of objective functions to equilibria of (non-cooperative) games.

Structural representations

- Graph-based representations are widely used in computer vision as a tool to abstract shape or scene structure
  - Captures relational arrangements
  - Provides contextual information needed to disambiguate part-identification
  - Invariant to scene transformations (rotation, change in viewpoint, …)
- Little work on classification of sample structure and on learning representations of the extracted classes and group invariants.

Why structural learning is hard

- Graphs are not vectors: There is no natural ordering of nodes and edges. Correspondences must be used to establish order.

- Structural variations: Numbers of nodes and edges are not fixed. They can vary due to segmentation error.

- Not easily summarized: Since they do not reside in a vector space, mean and covariance hard to characterize.

Structural model