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ACTIVITY REPORT 2010

TEAM

QGAR

Querying Graphics Through Analysis and Recognition

Research / Training / Transfer in an international context

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2. Overall Objectives

The Qgar project-team works on the conversion of weakly structured information—an image of a paper document, or a PDF file, for example—into "enriched" information, structured in such a way that it can be directly handled within information systems. Our research belongs to the document analysis field, and more precisely to the graphics recognition community. We study the use of graphics recognition methods to index and organize weakly structured graphical information, contained in *graphics-rich documents*, such as technical documentation. In this context, we experiment the capacity of pattern recognition methods to compute useful features for indexing and information retrieval. However, as the semantics (or domain knowledge) of the processed information cannot be fully taken into account, this community is well aware of the fact that recognition alone will not lead to completely automated back-conversion. Graphical information, such as symbols or drawing parts must be complemented with the handling of text-based retrieval (based on annotations or textual references, for instance) methods.

3. Scientific Foundations

Our scientific foundations belong in the domain of image analysis and pattern recognition. For many years, the main contributions of our project-team were in the area of algorithms and methods for image analysis and segmentation, with a specific focus on images of graphics-rich documents. In the last years, while keeping a regular activity in this domain, we have moved our main effort towards pattern recognition methods, especially for symbol recognition and spotting. But, of course, recognition tasks also require the prior extraction of features, using image processing and segmentation methods.

3.1. Feature Extraction and Segmentation

As conversion from pixels to features raises a great deal of problems, our project-team had to design several algorithms and methods for binarization [7], vectorization or text-graphics segmentation. However, designing new methods, or variants of older ones, is not enough. We also must be able to characterize and to evaluate the performances of the methods we use, to study their robustness and reliability, and to develop stable implementations for them (hence, the focus on software, cf. § 5.1).

Vectorization is the conversion of a binary image into a series of graphical primitives, mainly line segments and arcs of circle, generically called “vectors”, which are a good representation of the original graphics. Existing methods generally suffer from two major drawbacks, over-segmentation and poor geometric precision, especially at the junctions between vectors. We have worked for many years on this matter and proposed several techniques to overcome these limitations.

In particular, we have defined a new method based on Random Sample Consensus minimization, and uses techniques that are inspired from object tracking in image sequences. It is based on simple initial guesses, either based on connected line segments, or on elementary mainstream arc detection algorithms. Our method consists of gradually deforming these circular arc candidates as to precisely fit onto the image strokes, or to reject them if the fitting is not possible, this virtually eliminates spurious detections on the one hand, and avoiding non-detections on the other hand [14].

Performance evaluation is a major concern in document analysis, and more generally in image processing, pattern recognition and computer vision. A way of approaching the problem considers a method to be evaluated as a completely separate module, which is fed with synthetic or real data. Evaluation is then carried out by comparing the results supplied by the module with some ground-truth. The performance of a segmentation method may also be evaluated according to the observed qualities of recognition steps, using the features provided by the method. This is sometimes called “goal-oriented performance evaluation”.

We are actively involved in the organization of performance evaluation campaigns for symbol recognition, at national and international levels. More particularly, our project-team is leader of the Épeires project (cf. § 5.2), affiliated to the Techno-Vision program. This project aims at providing a complete environment of performance evaluation, for our own needs—as organizers—but also for the needs of any team working on symbol recognition or using recognition methods.

Performance evaluation of graphics recognition methods is related to several open scientific questions, including intricate problems such as defining simple and non-biased metrics and matching procedures between the ground-truth and the output of recognition methods, when the answer is more complex than a simple "recognized" or "not recognized" label—a good example is the evaluation of a vectorization method. Another potential problem is the generation of large sets of training or benchmarking data, using image degradation models. In this perspective we have a joint project with the Computer Center Vision at *Universitat Autònoma de Barcelona* on the characterization and evaluation of shape descriptors (cf. § 6.7).

3.2. Symbol Recognition and Spotting

Symbol recognition is the localization and identification of symbols in documents [28], to get natural features to be used in indexing and retrieval applications. Whereas it has ancient and solid foundations, and has proved to be mature for character recognition, for instance, symbol recognition still remains an open question when dealing with complex symbols having large variations and when symbols are embedded into the document. Our attention is focused on the weaknesses of the existing recognition methods, which make them difficult to use:

- In querying and browsing applications, it is often impossible to work with a database of reference symbols *a priori* known. It is more often the case that the user delineates an arbitrary symbol in a drawing and queries for similar symbols in the set of available documents. We therefore have to design methods allowing to recognize symbols, or at least to spot them "on the fly", without prior learning or precompilation of models.

- We are interested in coping with cases when a prior segmentation of the image is difficult, or even impossible, i.e., when it is necessary to design segmentation-free recognition methods or methods which simultaneously perform segmentation and recognition.

- Efficient methods for recognizing few symbols (less than 20 different models) are currently available. They work even when a symbol to be recognized is distorted by noise or by geometric transforms. However, they do not scale well to the recognition of a number of symbols an order of magnitude larger. Thus, there are both computational complexity issues and open questions about the discrimination power of methods chosen for recognition.

Signatures are often used for indexing and retrieval purposes, but most work has concentrated on text-based or image-based signatures. Nevertheless, we think that there is also room for graphics-specific signatures to achieve an efficient localization and recognition of symbols, and we currently work in two directions:

- Quick and robust symbol localization through image-based signatures: we propose to combine a feature descriptor method with a structural representation of symbols. We define a robust structural representation based on key points, which allows a quick localization of candidate symbols within documents. Each candidate is then recognized using a combination of shape descriptors.

- Structural shape signatures: direct work on the raw image data is not always necessary as, in many cases, vector data can be obtained from available CAD files or similar electronic representations, or can be captured through raster-to-vector conversion. It is therefore interesting to use signatures directly computed on such data.

When dealing with a large number of symbols, both signatures and structural recognition methods may not be powerful enough to discriminate. Combining outputs of classifiers or descriptors is one of the strategies used to improve recognition rates.

4. Application Domains

Our main application domain is the processing and analysis of documents—*i.e.* information produced by humans to communicate with other humans—which convey a huge amount of information in very "poor" formats: paper documents, or low-level, poorly structured digital formats such as Postscript, PDF or DXF.

We are more specifically interested in graphics-rich documents, typically technical documents containing text mixed with lots of graphics. The usual text-based indexing and retrieval methods are still of interest, but we also need additional ways of accessing the information conveyed by documents: recurring symbols, connections between textual descriptions and drawing parts, etc. Within this general application area, we work on two major kinds of document analysis applications:

- Specific documentation referring to a well-known framework of technical knowledge: a good knowledge about the type of information which has to be extracted from the documents is usually available, in terms of models of the symbols to be recognized. This is the case of architectural floor plans, like those of the European SCANPLAN project in which we participate (cf. § 7.2).
- Open documentation: few or even no strong assumptions are made on the kind of information to handle. This is typically the case of applications for browsing large sets of heterogeneous documents, when the user provides "on the fly" information about the symbols or structures he is looking for.

5. Software

5.1. Qgar Software

Participants: Philippe Dosch.

Overview Since several years, the QGAR project-team has devoted much effort to the construction of a software environment, to be able to reuse whole or part of software implemented during previous work, as well as collected experience. This environment includes three main parts:

- *QgarLib*, a library of C++ classes implementing basic graphics analysis and recognition methods,
- *QgarApps*, an applicative layer, including high-level applications (binarization, edge detection, text-graphics separation, thick-thin separation, vectorization, etc.),
- *QgarGUI*, a graphical interface to design and run applications, providing data manipulation and display capabilities.

The Qgar system is registered with the French agency for software protection (APP) and may be freely downloaded from its web site (`http://www.qgar.org`). The whole system is written in C++ and includes about 170,000 lines of code, including unit test procedures. A particular attention has been paid to the support of "standard" formats (PBM+, DXF, SVG), high-quality documentation, configuration facilities (using CMake), and support of Unix/Linux and Windows operating systems.

Application management is plugin-based. Each executable binary file is paired with a XML description file which is parsed when the user interface is launched: the corresponding application is then dynamically integrated into the menus of the interface, and dialog boxes to access the documentation and run the application are dynamically generated. In this way, any application may be easily coupled with a remote system based on a similar approach. Conversely, as the integration (or removal) of an application does not imply any modification of the user interface, the installation of remote applications, provided by partners for testing for example, is easy. This is particularly useful when comparing different methods performing the same task, in the context of performance evaluation, a topic which is part of our current research work, as previously mentioned. downloaded on 10 times visits are by of several

This year, Qgar Software has essentially received attention for bug corrections. The objective has been to propose a more mature code, still available under Linux as well as under Windows. The whole package, including all the components, is proposed under several formats (gzipped tar archive, DEB package, Windows installer) in order to provide different easy ways to install Qgar, on most of existing platforms.

For 2011, we still plan to integrate a lot of experimental code of the Qgar development library or belonging to the QgarApp component. It has to be progressively refactored either to be included into the Qgar platform or updated according to the last specifications of the platform (for those already included). As the whole Qgar software now relies on up-to-date library (Qt4) and tool (CMake), we plan to pay our attention on these integrations in order to provide a software as useful and attractive as possible, for our own needs as well as for those of the community.

5.2. The Épeires Environment

Participants: Philippe Dosch.

Techno-Vision is a French national program to fund projects related to performance evaluation of vision algorithms in computer science. We have been leaders of the Epeires project[1] on performance evaluation of symbol spotting and recognition (2005–2007) and, as such, in charge of the scientific animation, of the creation of the information system related to the project, and of the creation of the testing data which have been used during evaluation campaigns, like the three editions of the International Contest on Symbol Recognition, organized during the last GREC workshops. In this context, we have improved the Epeires framework, a complete information system, capable of managing all required data related to performance evaluation of symbol recognition methods. It includes the management of data themselves, but also of their classification, of the automatic degradation processes, of the participant profiles, and of the available tests and result storage. This environment has been developed using the *Ruby on Rails* framework (`http://www.rubyonrails.org/`), and is available at the web site of the project, hosted at `http://www.epeires.org`.

The web site is also the location where all resources related to the project are freely available to the scientific community. In this way, users are able to declare their methods, and the related characteristics, to generate testing evaluations for specific purposes or to download existing ones, and to send and analyze their results. The same functionalities are provided to the organizers (Épeires Consortium).

We also developed a collaborative ground-truth managing software, called Picvert, coded in Java and hosted at `http://gforge.inria.fr/`. It is used to create, review and validate test-image labellings with respect to reference symbols (ground-truth). Its architecture is based on a client/server model connected to the information system. At the same time, we added functionality directly to the website so as to enable the creation and validation of ground-truth online.

The web site is fully operational, and we continue to improve it, by adding new functionalities and by refining the existing content.

6. New Results

6.1. Document Segmentation

Participants: Thanh Ha Do, Mehdi Felhi, Thai Hoang Van, Hervé Locteau, Salvatore Tabbone.

Recently, we have witnessed an explosion of interest from mathematicians and computer scientists in sparse representation of multi-dimentional signals. Representing sparsely means that we need only a small number of elementary signals to represent an input signal. This is possible if we can remove most of redundancy

[1] `http://www.epeires.org/`

in the representation. According to Barlow's principle of redundancy reduction, sparse representation could provide a more efficient representation of signals for later processing stages. Many applications in computer vision and pattern recognition based on sparse representation have emerged recently. Significant examples are object recognition, signal classification, image super-resolution, face recognition. In the field of document analysis and recognition, sparse representation have been applied to digit recognition and text segmentation from complex background. It is believed that more and more applications of sparse representation will appear in the near future.

We have the following new results:

- Edge noise removal: results in computational hamornic analysis show that curvelet frames which contain multi-scale, multidirectional, and elongated curvelets can provide an optimal representation of objects with edges. Most of the energy of the objects is localized in just a few coefficients of curvelets which overlap and are nearly tangent to the object contours. In other words, the directional information of object contours is encoded in a small number of curvelet coefficients. Combining this code with the basis pursuit denoising algorithm will constitute a sparse representation framework allowing directional denoising along object contours. This work has been done in collaboration with E. Barney-Smith during her stay in 2009 in the Qgar team.

- Text/graphics separation: a document image y containing text and graphics components is considered as a two-dimensional signal which is the mixture of two separate two-dimensional signals (images) of the same size: y_t containing text components and y_g containing graphics components. The problem of text extraction is now seen as the recovery of y_t and y_g from y. To solve this, we employ the Morphological Component Anaysis (MCA) method. MCA allows the separation of features contained in an image when these features present different morphological aspects. This is facilitated by promoting sparse representations of these features in two appropriately chosen dictionaries each leads to sparse representation over one feature and non-sparse representation over the other. Having done in this way, some post-processing steps could be needed to extract text strings from y_t. This is done with the help of some heuristic rules based on the discriminative characteristics of text components. The proposed method is thus robust to touching between characters and graphics[23, 11]

In the image analysis system, the segmentation constitutes one of the most significant problems because the result, obtained at the end of this stage, strongly governs the final quality of interpretation. Many segmentation methods are quoted in literature among which some are based on parametric approaches where the classes constituting the various image partitions are, in one hand, separated by (1) considering a statistical model to approach the class probability density functions (PDF) and in the other hand, by (2) determining the threshold optimal values as functions of the class parameters (case of the multi-thresholding) or the estimates of the posterior probabilities for the various classes depending on the considered model parameters (case of the mixture models).

The major part of the parametric approaches considers mixture models using the Gaussian distribution (Gaussian Mixture Models) for their simplicity of computation. However, the PDF of a real image may be inherently non-Gaussian or even a mix of several distributions, so using a GMM cannot portray the data accurately. To this end and to overcome to the limitations presented by such models, we propose a mixture model based on the generalized Gaussian distribution (GGMM) as an alternative model so that the resulted image partitions match as best as possible with the various semantic components contained in the real image. Indeed, this model can describe in the best possible way the class statistical behaviour in the image because the generalized Gaussian distribution (GGD) can approximate a large class of statistical distributions (e.g. impulsive, Laplacian, Gaussian and uniform distributions). This modelling capacity confers to this model and interesting property named flexibility[18] .

For the SCANPLAN research transfert project (cf. 7.2), we deal with architectural floor plan image analysis . For the first prototype, the main components that have to be identified are walls, doors, windows and rooms. We have proposed to apply techniques used in Computational Geometry to decompose a floor plan into rooms. There, a room is regarded as a nearly convex polygon. Once walls have been detected, the outer boundary of the house is identified from the convex hull while the remaining walls have to be connected to separate each component of the building. A top-down hierarchical approach is used to identify the most significant singularities from which a separation has to be drawn. The overall performance of such a framework is an ongoing task on real documents but preliminary results are promising [26].

In [17], we have extended the previous work introducing clues in the segmentation. We take advantage of the door hypothesis to favor separations located in theirs vicinities. At each step, we rank a set of separation hypothesis from a combination of functions. It allows to introduce domain dependent knowledge within a reliable segmentation framework. Indeed, (1) false detections are just ignored and (2) a separation can be proposed while the corresponding door may be missed.

The processing of the *text layer*, when it exists, is a ongoing task to enhance the precision of the rooms' definition with respect to theirs dimensions.

6.2. Shape Descriptors

Participants: Thai Hoang Van, Salvatore Tabbone.

The Radon transform converts the geometric transformations applied on a shape image into transformations in the radial and angular coordinates of the Radon image. Radon-based invariant shape descriptors are different from the others in the sense that Radon transform is used as an intermediate representation upon which invariant features are extracted from for the purpose of indexing/matching. The reasons for the utilization of the Radon transform are:

- It is a rich transform with one-to-many mapping. Each shape point lies on a set of lines in the spatial shape image and contributes a curve to the Radon image.
- It is a lossless transform, shape image can even be reconstructed by an inverse Radon transform.
- It has useful properties concerning geometric transformations applied on a shape image.
- It has low complexity, it requires $\mathcal{O}(N^2 \log N)$ operations for an input image of N pixels.

New directions for the utilization of the Radon transform for invariant shape representation have been explored:

1. Use the Radon, $1D$ Fourier-Mellin, and Fourier transforms sequentially. In this method, invariances to translation, rotation, and scaling are obtained by applying the $1D$ Fourier-Mellin and Fourier transforms on the radial and angular coordinates of the Radon image respectively [10].
2. Generalize the $\mathscr{R}-$signature[38]. A family of shape descriptors, parameterized by the exponent of the $\mathscr{R}-$signature are obtained. The generalized $\mathscr{R}-$signature, in the one hand, inherits invariant properties of the original $\mathscr{R}-$signature, and in the other hand, has higher discriminatory power. In this perspective, a new shape descriptor, called $\phi-$signature, which is complementary to the $\mathscr{R}-$-signature transformation by considering the line elements in the Radon matrix has been proposed [27, 19].

6.3. Combination of Classifiers and Shape Descriptors

Participants: Sabine Barrat, Salvatore Tabbone.

Combining outputs of classifiers, descriptors, or selecting features is one of the strategies used to improve classification rates in common classification. We tackled the problem of combining classifiers within a non-Bayesian framework, considering both two-class and multi-class classifiers [4]. A classifier is assimilated to a random variable and finding the best classifier combination is expressed as solving an optimization problem.

We are also interested in combining image descriptors and text modes. We have chosen to use probabilistic graphical models, especially Bayesian networks. In fact, these models allow for combining different types of information inside a same network, and for managing missing data. We have proposed an original adaptation of such networks to the problem of visual descriptors combination for image classification and to represent weakly annotated images and semantic relations between keywords. These models can be used to classify images and automatically extend existing annotations to new images [6, 22, 8].

Finally, the same models can be used to combine continuous shape descriptors and discrete shapes measures in order to recognize symbols in large and complex databases. We showed that this feature combination increases the recognition rate. Moreover, the proposed model is competitive with state-of-art classifiers [5].

6.4. Scaling of Symbol Recognition Methods

Participants: Salim Jouili, Salvatore Tabbone.

Storing and querying high-dimensional data are important problems in designing an information retrieval system. When handling a large database, a system needs an efficient index mechanism to retrieve data by their contents. In this perspective, we are interested in methods of information retrieval in masses of documents represented with structural form. When used for graphic documents, such methods are well appropriate to pattern recognition because they offer a rich framework to describe symbols of unspecified shapes and structural relations between them. We propose a hypergraph structure [24], extending the concept of median graph to a median set of graph for large graphs database. This extension helps to cluster graphs and allows the number of clusters to vary with database size and data characteristics. We use the minimum common supergraph to represent our clusters that are in fact the hyperedges of a hypergraph structure. This research takes place in the scientific environment of project Navidomass (Navigation In Document Masses of the call to project ANR MDCA) related to indexing large dabases of ancient cultural heritage documents [33], [12].

6.5. Structural-Based Descriptors Applications

Participants: Salim Jouili, Hervé Locteau, Salvatore Tabbone.

In document retrieval applications, it is necessary to define some description of the document based on a set of features. These descriptions are then used to search and to determine which documents satisfy the query selection criteria. The effectiveness of a document retrieval system ultimately depends on the type of representation used to describe a document. In pattern recognition, the document representation can be broadly divided into statistical and structural methods. In the former, the document is represented by a feature vector, and in the latter, a data structure (e.g. graphs or trees) are used to describe objects and their relationships in the document.

We observed that the classical retrieval systems are often limited to work with a statistical representation due to the need of computing distances between documents (feature vectors) or finding a representative of a cluster of documents. However, when a numerical feature vector is used to represent the document, all structural information is discarded although the structural representation is more powerful in terms of its representational abilities. In the last decades, many structural approaches have been proposed. These approaches deal, especially, with graph-based representations. Nevertheless, dealing with graphs suffers, on the one hand from the high complexity of the graph matching problem which is a problem of computing distances between graphs, and on the other hand from the robustness to structural noise which is a problem related to the capbility to cope with structural variations and differences in the size of the graph. In order to overcome this problem, several approximate graph matching methods have been proposed. In this vein, firstly our attention is focused on the comparison of different graph similarity measures in the context of document retrieval [29]. Secondly, a node signatures extraction is combined with an optimal assignment method for approximating graph edit distance [2]. In particular, we shown how local descriptions are used to define an assignment problem which can be solved by the Hungarian method. In addition, the proposed framework computes implicitly a large part of the graph edit distance during the processing of the assignment problem. Therefore, we demonstrate that the graph edit distance formula can be written with the optimum solution of the assignment problem. The set of experiments demonstrates that the newly presented algorithm is well-suited to pattern recognition applications. Compared with well-known methods, our algorithm gives good results for retrieving graphs. In addition, in the context of retrieving graphs we introduced a prototype-based clustering algorithm dealing with graphs. We proposed a hypergraph-based model [24] for graph data sets by allowing clusters overlapping. More precisely, in this representation one graph can be assigned to more than one cluster. Using the concept of the graph median and a given threshold, the proposed algorithm detects automatically the number of classes in the graph database. We consider clusters as hyperedges in our hypergraph model and we define a retrieval technique indexing the database with hyperedge centroids. This model is interesting to travel the data set and efficient to cluster and retrieve graphs.

Additionally, in the context of unsupervised clustering, a new algorithm for the domain of graphs is introduced [13]. The key idea of our algorithm is to adapt the mean-shift clustering and its variants proposed for the domain of feature vectors to graph clustering. These algorithms have been applied successfully in image analysis and computer vision domains. The proposed algorithm, namely the graph median-shift, works in an iterative manner by shifting each graph towards the median graph in a neighbourhood. Both the set median graph and the generalized median graph are tested for the shifting procedure. In the experiment part, a set of cluster validation indices are used to evaluate our clustering algorithm and a comparison with the well-known K-means algorithm is provided.

Unlike for structural-based representation, a lot of robust classification approaches have been developed for the feature vector representation. In contrast, the classification of graphs is limited to the use of the nearest-neighbor classifiers using one graph similarity measure. On that account, the community of pattern recognition speaks about a gap between structural and statistical approaches. Recently, a few works have been carried out concerning the bridging of this gap between structural and statistical approaches. Their aim is to delineate a mapping between graphs and real vectors, this task is called graph embedding. The embedding techniques were originally introduced for statistical approaches with the objective of constructing low dimensional feature-space embeddings of high-dimensional data sets [36]. We proposed a graph embedding technique [30] based on the constant shift embedding [36] which transforms a graph to a real vector. This technique gives the abilities to perform the graph classification tasks by procedures based on feature vectors. Through a set of experiments we show that the proposed technique outperforms the classification in the original graph domain and the other graph embedding techniques.

In [25], we have investigated a new framework to solve the subgraph isomorphism problems with Integer Linear Program. When we are looking for an injective function from a queried graph to a host graph, that is to say, when dealing with univalent matching, the problem can be solved using a mathematical solver given a serie of constraints. They are defined to obtained exact matching from the graph topology point of view. This framework has been validated on a symbol detection application encoding images with Attributed Relational Graphs. Vertices and edges are labelled with feature vectors, describing respectively the shape of a region and geometrical constraints between a pair of regions. To be error tolerant on labels, no classification is applied. Experiences show the proposed system is able to recover the most similar regions to the queried symbol on synthetic documents build from [34]. For further works, we plan to control the number of returned regions per queries and to extend the framework to inexact subgraph isomorphism.

6.6. Symbols recognition and spotting

Participants: Santosh K.C., Bart Lamiroy, Amani Boumaïza, Hervé Locteau, Oanh Nguyen, Salvatore Tabbone.

Complex, composite, documents contain textual and graphical elements. In order to fully exploit the information embedded in those documents, one needs to be able to extract and formalize the links that exist between the images and the surrounding text. Correct extraction and representation of both visual data, textual and linguistic structures and global document structure and organization are the first steps towards further automated knowledge discovery, information discovery and information retrieval or data mining on more complex data than just text.

This theme is developed according to three major axis:

1. the extraction of robust visual elements (vocabulary) that compose an image;
2. the expression of visual relations between the elements;
3. knowledge discovery, formal learning techniques and classification using the vocabulary and relations mentioned above.

Previous work has consisted in using *Inductive Logic Programming* to automatically learn non-trivial representations of the symbols, based on a formal description [37, 35]. The results have shown that the quality of the used vocabulary was an essential part of it and should be further investigated.

We have been focusing on extending work on spatial relation models [31] and have used it as a basis for symbol description, recognition and retrieval [21]. Our spatial relations handle fuzzy relations that convey a degree of truth rather than using standard, all-or-nothing relations. The corresponding recognition method consists of first classifying the vocabulary elements into different groups based on their types: *circle*, *corner*, *extremity* and *thick* (filled) patterns. We then compute spatial relations between the possible pairs of labelled vocabulary types and use them to construct an Attributed Relational Graph. The apropriate choices and the fact that the graph attributes exploits spatial as well as structural information allows us to avoid the general NP-hard problem arising from sub-graph matching and do recognition and matching in constant time.

We have compared the performance of our spatial relation model by measuring its discriminant power compared to other standard spatial relation approaches (*Cone-shaped*, *Angle Histogram* and *Minimum Boundary Rectangle*). Our method outperforms the existing ones by more than 40%. The resulting recognition method was compared to global signal based descriptors: *Zernike*, *Generic Fourier Descriptor*, *Shape Context* as well as $\mathscr{R}-$signature. Our method performs by more than 10% from the best performing algorithm in those categories.

The experience gathered from studying spatial relations has also been applied to online handwriting recognition[2] [20]. Our spatial relations were combined with order free stroke clustering to obtain writer independent handwritten Devanagari character recognition. Strokes are hierarchically agglomerated via Dynamic Time Warping, based on their location and their number. In contrast to previously published results, we improved performance both in terms of recognition rate (95%) and running time (60% reduction).

In order to enhance the extraction of visually significant parts of an image, we have been working on using bag of shape features for part of our existing vocabulary types. By applying hierarchical clustering based on discriminative shape descriptors, we are trying to learn local distinctive shapes, representative of the symbol in its context. For this, we have combined a collection of descriptors (GFD, *Zernike*, *Shape Context* ...) to different hierarchical clustering linkage methods and cluster validation indices (*Dunn*, *Silhouette*, *Davies-Bouldin*, *Score-Function*).

As for the works above mentionned, symbol spotting concerns the retrieval of objects similar to a query within a database of images. While Content Based Image Retrieval imply to identify images being perceptually similar, taking into account spatial relations, the on-the-fly recognition deals with detection of component of images. The latter are named *regions of interest* as they are regarded as similar to the sample used as a query. We report in [28] a survey on symbol spotting and in the same vein we propose a method[9] based on visual vocabulary and which is an original adaptation of information retrieval techniques. This topic is still challenging because of the appeal for preprocessing steps that introduce noise, heuristics to face computational complexity issues in existing works.

[2] The work is partially based on Master Thesis: TC-MS-2006-01, conducted in (and in collaboration with) Knowledge Information & Data Management Laboratory, School of ICT, SIIT, Thammasat University, Thailand

6.7. Evaluation and Benchmarking

Participants: Philippe Dosch, Santosh K.C., Salvatore Tabbone.

Since the end of 2004, our project-team is leader of the Épeires project affiliated to the Techno-Vision campaign. The objective is the construction of a complete environment for performance evaluation of symbol recognition and localization methods. This topic has gained increasing interest in the last years, as demonstrated by the creation of three international contests on symbol recognition methods [39]. We began to work on a new interface allowing interactive definition of ground-truthing. Our former ground-truthing management software was written in Java. The new one now take advantage of the new Web standards like HTML 5a and AJAX. As a result, all the tools proposed by the Épeires project will soon be directly available from its associated Web site. (cf. § 5.2).

In collaboration with CVC at University of Barcelona as part of the SYMBOLREC associated team (cf. § 8.2.2), we also started a new project about characterization of shape descriptors, in order to define a "genetic map" of selected descriptors, that is to say a list of properties some families among them share. These properties must not be dataset-dependent. We hope that such a map will lead to the definition of usage profiles, so that a user facing a practical pattern recognition problem can get help in choosing the most appropriate family of descriptors. Such a protocol must be independent of datasets to be of general use. Evaluation models are easy to implement when they are dataset-driven, as they just require the computation of some recognition rates on a given dataset. However, they do not give much information about the behavior of a descriptor on a different dataset. Our aim is the design of dataset-independent models, which is a more ambitious and a more complex task.

We are interested both in pixel-based descriptors, computed on all pixels of the shape or on a subset of these pixels (contours, or regions, for example), and in structural descriptors, computed from the components of the shape and from the relationships between them. Each descriptor must be evaluated in terms of computational complexity, of robustness to geometric transformations and image degradations, of genericity, and of separability and compactibility. The last two criteria give a measure of the discrimination power of a descriptor when the number of classes and the variability of the shapes grow.

It is extremely important for the Document Image Analysis and Recognition community to be able to cross check and reproduce results described in published papers in the field. In order to achieve this, any datasets used as the basis for publications should be publicly available, as is the norm in many other disciplines. We make public such a database for the recognition of on-line handwritten Devanagari characters[3].

We have used a simple Graphite tablet to capture the pen-tip position in the form of 2D coordinates.

The data set was composed of 1800 characters from 36 classes of characters, where 25 natives were used. Each writer had given a chance to write two times per class of character. As no directions, constraints, and instructions were given to the users, the dataset was completely composed of natural handwritings as if they were writing on a piece of paper.

The digitizer captures a series of strokes during pen movement. A string of coordinates (pen-tip positions) from pen down to pen up movement represents a stroke. Variable numbers of strokes are used to complete a character from time to time writing and from one user to another.

For our own work [20], we made writer independent character recognition system – first 15 writers were taken as training while remaining 10 were for testing.

[3] http://www.iapr-tc11.org/mediawiki/index.php/Devanagari_Character_Dataset

7. Contracts and Grants with Industry

7.1. OCE Print Logic Technologies

Participants: Mehdi Felhi, Salvatore Tabbone.

Océ is a company focused on hardware (printers, copiers and scanners), software, services and imaging supplies. Until november 2010, it pays the salary of Mehdi Felhi, a PhD student under a CIFRE contract, who works on complex documents segmentation in order to improve the image quality of a printing system.

7.2. ScanPlan Project

Participants: Amani Boumaïza, Hervé Locteau, Oanh Nguyen, Salvatore Tabbone.

ScanPlan is technological transfer project dealing with floor plan image analysis that started two years ago. It is an European project with the Eureka label. The aim is to develop working prototypes with document image analysis and pattern components in order to recognize raster images or vectorial files of architectural floor plans. The main challenge is to provide a new help process to the user in defining its own house plan. Since the target market will be the consumer market, we have to automate as much as possible the interpretation of the input document, devoting user interaction to meaningful step. The efficiency of the detection will be mainly evaluated from an ergonomic view point : errors have to be minor and easy to correct.

The partners of the project are Anuman Interactive (France), Centro de Visio per Computador (Spain), and Icar Vision Systems (Spain).

8. Other Grants and Activities

8.1. National Actions

8.1.1. Navidomass

Participants: Salim Jouili, Salvatore Tabbone.

The NAVIDOMASS project was accepted by the scientific committee of ANR in Fall 2006 and started at the beginning of 2007. It is a research proposal to the ANR call on Data Masses (ARA MDCA). The general purpose is the construction of a framework to digitally preserve and provide universal access to heritage document collections in libraries, museums and public archives. The main focus is the navigation in large databases of archives containing text, images, illustrations and schemas, through the extraction of knowledge from images of documents.

Our partners are the IMADOC group at IRISA in Rennes, Centre d'Études Supérieures de la Renaissance in Tours (CESR, UMR 6576), and the universities of La Rochelle, Tours, Rouen and Paris 5.

8.2. International Cooperation

8.2.1. AIDA

Participants: Hervé Locteau, Salvatore Tabbone.

Collaborations supported by the Euromed 3+3 program and Volubilis program started in 2009. Our project concerns the archiving and indexing of arabic documents. Our partners in this project are the universities of: Annaba (Algeria), Rouen (France), Agadir (Marocco), Barcelona (UAB Barcelona, Spain) and Sousse (Tunisia). Through this project, several PhD students Amina Ghardallou (Sousse, in december 2010), Chaouki Boufenar (Annaba, in November 2010), Fattah Zirari (Agadir, in June 2010) got the opportunities to visit our team.

8.2.2. CVC Barcelona

We intensified our long-lasting scientific cooperation with the Computer Vision Center at *Universitat Autònoma de Barcelona*, including joint PhD supervisions, student, regular researcher and post-doc exchanges, collaboration in the Techno-Vision Épeires project, INRIA associated team SYMBOLREC[4], funding through PAI Picasso for joint work, joint European proposal, and joint organization of international symbol recognition contests.

We also continue our joint project on the characterization and evaluation of shape descriptors (cf. § 6.7) [29].

8.2.3. IDEA

Participants: Salvatore Tabbone.

IDEA (Images of natural Disasters from robot Exploration in urban Area) is a regional programme *Ict*-Asia. Its aim is the development of an expertise about image processing and computer vision for urban natural disasters, when using a camera mounted on a patrolling robot as a mobile sensor on disaster sites. More precisely, it proposes a new research direction to make it easy to identify images and to take decision about rescue management after a natural disaster. Our partners in this project are team *Modélisation et Simulation Informatique de systèmes complexes* at *Institut de la Francophonie pour l'Informatique* of Hanoi (Vietnam), Institute of Information Technology of Hanoi, *Universiti Kuala Lumpur Malaysia*, and *Laboratoire Informatique, Image, Interaction* (L3I) at *Université de La Rochelle*.

8.2.4. Lehigh University

Participants: Bart Lamiroy.

During 2010, Bart Lamiroy was a visiting scientist at Lehigh University. During his stay he has been in charge of developing a generic Document Analysis platform for representing research data from document images (text, graphic, picture)[16, 15]. This joint research effort is having widespread implications and is planned to be used as a basis for ground truthing references and international benchmarking efforts.

9. Dissemination

9.1. Animation of Scientific Community

9.1.1. Journals

Salvatore Tabbone is member of the editorial board of Journal of Universal Computer Science (JUCS).

Karl Tombre is editor in chief of the International Journal on Document Analysis and Recognition (IJDAR), member of the advisory board of Electronic Letters on Computer Vision and Image Analysis (ELCVIA), and

[4] `http://dag.cvc.uab.es/symbolrec/`

member of the editorial board of Machine Graphics & Vision and of *Revue Africaine de la Recherche en Informatique et Mathématiques Appliquées* (ARIMA).

9.1.2. Associations

Salvatore Tabbone is president of the GRCE (Groupe de Recherche en Communication Écrite) since December 2010.

Karl Tombre was past-president of the International Association for Pattern Recognition (IAPR until august 2010.

9.1.3. Other Responsibilities

- Bart Lamiroy is elected to the scientific council of INPL.

  He is a member of *Comité de suivi de l'espace transfert*, which follows and evaluates spin-offs and start-ups resulting from research works carried out in LORIA.

  He is an active member of the Education Commission of the Information Technology Service Management Forum (itSMF) France.
- Karl Tombre is the director of the INRIA Nancy-Grand Est Research Center. His main duty is therefore to manage a large research center of about 450 persons. In 2010, Karl Tombre chaired the AERES evaluation committee for L3I in La Rochelle and was member of the evaluation committee for LINA in Nantes.
- Salvatore Tabbone and Karl Tombre are members of the administrative council of AFRIF (French Association for Pattern Recognition and Interpretation).

9.2. Collaborations within INRIA

We regularly work with the IMADOC group at IRISA, a partner of our new NAVIDOMASS project (cf. § 8.1.1) on heritage documents.

9.3. Teaching

Most members of the QGAR project-team are university faculty members and, as such, have a statutory teaching service in their respective universities, cumulated, for several of them, with major organizational and administrative responsibilities. They have teaching positions at various institutions:

- Philippe Dosch, at Université de Nancy 2, at bachelor level.

  He is the director of studies for the bachelor degree "Administration of open source systems, networks and applications".
- Bart Lamiroy, at *Institut National Polytechnique de Lorraine/École des Mines de Nancy* (engineering school, master of engineering level).

  He heads the Department of Computer Science, and is the technical coordinator of the IPISO specialized degree.
- Benoît Naegel, at Université Henri Poincaré Nancy 1/IUT de Saint-Dié des Vosges (at bachelor level).
- Salvatore Tabbone, at Université de Nancy 2, at bachelor and master level. He also heads one of the computer science masters (M2 Miage-ACSI) of Université de Nancy 2.

9.4. Conference and Workshop Committees

- Philippe Dosch was/is member of the program committee of CIFED'2010 (Colloque International Francophone sur l'Écrit et le Document, Sousse, Tunisia), and ICPR'2010 (20th International Conference on Pattern Recognition, Istanbul, Turkey).

- Bart Lamiroy is member of the program committee of CIFED'2010 (Colloque International Francophone sur l'Écrit et le Document, Sousse, Tunisia).

- Salvatore Tabbone was/is member of the program committees of CIFED'2010 (Colloque International Francophone sur l'Écrit et le Document, Sousse, Tunisia), RFIA'2010 (17e Congrès Francophone sur la Reconnaissance des Formes et l'Intelligence Artificielle, Caen, France), CARI'2010 (10e Colloque Africain sur la Recherche en Informatique et en Mathématiques Appliquées, Yamoussoukro, Côte d'Ivoire), ITS'2010 (International Telecommunications Symposium, Manaus, Amazonas, Brazil), ACMSAC'2010 (25th Symposium On Applied Computing, Sierre, Switzerland), ICISP'2010 (International Conference on Image and Signal Processing, Trois-Rivières, Québec, Canada), GBR'2011 (8th Workshop on Graph-based Representations in Pattern Recognition, Münster, Germany), ORASIS'2011 (13e Congrès Francophone des Jeunes Chercheurs en Vision par Ordinateur, Praz-sur-Arly, France) and ACMSAC'2011 (26th Symposium On Applied Computing, TaiChung, Taiwan),

- Karl Tombre was/is member of the program committee of DAS'2010 (9th International Workshop on Document Analysis Systems, Cambridge, MA, USA) ICPR'2010 (20th International Conference on Pattern Recognition, Istanbul, Turkey), ICTAI'2010 (22th IEEE International Conference on Tools with Artificial Intelligence, Arras, France), CIFED'2010 (Colloque International Francophone sur l'Écrit et le Document, Sousse, Tunisia), ICCVG'2010 (International Conference of Computer Graphics and Vision, Warsaw, Poland), ASPIRE'2010 (1st International Workshop on Advances in Patent Information Retrieval, Vienna, Austria), CIAPR'2010 (XV Iberoamerican Congress on Pattern Recognition, Sao Paulo, Brazil), ICDAR'2011 (11th International Conference on Document Analysis and Recognition, Beijing, China), IBPRIA'2011 (5th Iberian Conference on Pattern Recognition and Image Analysis, Las Palmas de Gran Canaria, Spain), and CAIP'2011 (14h International Conference on Computer Analysis of Images and Patterns, Sevilla, Spain)

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