INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team Qgar

Querying Graphics Through Analysis and Recognition

Lorraine

THEME COG

Activity Report

2004

Table of contents

1. Team

QGAR *is a research project of* LORIA.

Team Leader
Karl Tombre [professor, INPL[1]-École des Mines de Nancy]

Administrative Assistant
Isabelle Herlich [TR INRIA]

Inria staff
Jan Rendek [junior technical staff until August 2004]
Laurent Wendling [assistant professor, UHP[2], on an INRIA researcher scientist position until August 2004]

Cnrs Staff
Gérald Masini [research scientist]

University taff
Suzanne Collin [assistant professor, ESIAL, UHP]
Philippe Dosch [assistant professor, Université Nancy 2, IUT de Nancy-Verdun]
Bart Lamiroy [assistant professor, INPL-École des Mines de Nancy]
Salvatore Tabbone [assistant professor, Université Nancy 2]
Laurent Wendling [assistant professor, ESIAL, UHP, from September 2004]

Post-doctoral Fellow
Xavier Hilaire [post-doc in New Zealand until August 2004, then Lectrurer (temporary research and teaching position) UHP]

Ph. D. Students
Jan Rendek [CIFRE contract with France Télécom, from October 2004]
Jean-Pierre Salmon [FRESH contract, from December 2004]
Daniel Zuwala [MENRT grant]

2. Overall Objectives

Our group works on the conversion of weakly structured information—such as the image of a paper document, or a PDF file, for instance— into "enriched" information which is 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. However, this community is perfectly aware of the fact that recognition alone is not sufficient, and will not lead to fully automated back-conversion. This is mainly due to the problem of taking completely into account the semantics (or domain knowledge) of the information which is processed.

Our group aims at using graphics recognition methods to index and structure weakly structured graphical information, contained in *graphics-rich documents* such as technical documentation. In these cases, text-based retrieval (on annotations or textual references, for instance) must be complemented with the handling of purely graphical information, such as symbols or drawing parts. We are interested in exploring the capacity of graphics recognition to compute useful features for indexing and information retrieval in technical documentation.

3. Scientific Foundations

3.1. Feature extraction and segmentation

Keywords: *Binarization*, *color processing*, *image processing*, *text-graphics segmentation*, *vectorization*.

[1] Institut National Polytechnique de Lorraine.
[2] Université Henri Poincaré Nancy 1.

Participants: Suzanne Collin, Xavier Hilaire, Salvatore Tabbone, Karl Tombre, Laurent Wendling.

The processing and segmentation of document images has been a central theme of our research for many years already, as good performance of the whole analysis process heavily depends on the robustness, precision and reliability of the low-level features extracted from the scanned image. There are a number of algorithmic problems in the conversion from pixels to features. Our group has designed several algorithms and methods for binarization, vectorization or text-graphics segmentation. However designing new methods, or variants of older methods, is not enough. We also must be able to characterize and evaluate the performances of the methods we use, to study their robustness and reliability, and to have stable implementations for them (hence, the focus on software, see. § 5.1).

3.1.1. *Quality and precision of raster-to-vector conversion*

Participants: Xavier Hilaire, Karl Tombre.

Vectorization consists in converting a binary image into a series of graphical primitives (vectors and circular arcs), which are a good representation of the original drafted figure. We have worked for many years on this problem, and have proposed several algorithms. As most of the existing methods have two major drawbacks, over-segmentation and poor geometric precision, especially at the junctions between vectors [32], the focus of our work on vectorization has been to overcome these limitations.

3.1.2. *Robustness and genericity of segmentation algorithms*

Participants: Suzanne Collin, Salvatore Tabbone, Karl Tombre, Laurent Wendling.

Too often, feature extraction methods rely on a number of parameters which must be fine-tuned from one application to the other. We aim at defining robust and stable methods, with as few parameters as possible, by studying the relationship between the values of the parameters, the data to be processed, and the results yielded. Let us cite three segmentation problems:

- *Binarization* can be defined as the partitioning of an image into two classes: Shape and background. It is a fundamental step in document analysis systems. Many methods exist, but few studies have looked more specifically at the problems found with documents containing simultaneously text and graphics. We are exploring various approaches, especially some methods based on fuzzy logic, which do not necessitate any manually set thresholding parameter.
- *Text-graphics segmentation* consists in separating image parts considered to be of textual nature from other parts supposed to be graphics. Most existing methods are based on the analysis of connected components. We have improved existing methods to achieve higher-quality segmentation, including steps to retrieve the parts of the text which touch the graphics [33].
- *Color processing and segmentation* can bring additional features to higher-level analysis steps such as symbol recognition. It is therefore important to be able to separate color layers in a scanned document.

3.1.3. *Performance characterization and evaluation of segmentation and recognition algorithms*

Participants: Philippe Dosch, Xavier Hilaire, Karl Tombre.

Performance evaluation is a major concern in document analysis, and more generally in image processing, pattern recognition and computer vision. There are different approaches to the problem. The first is to consider the method to be evaluated as a completely separate module, which is fed with synthetic or real data. Evaluation then consists in comparing the result of the module with some ground truth. The second approach consists in evaluating the performances of a segmentation method by the observed qualities of recognition steps using the features yielded by the segmentation. This is sometimes called goal-oriented performance evaluation [35].

We have recently reformulated the problem of matching ground truth with extracted features, and we have proposed an evaluation protocol for vectorization methods [30]. The matching method uses only a single threshold parameter, and is based on some elementary, intuitive rules. This work showed that the problem of matching a vectorial representation of a given image against its ground truth not only could be considerably simplified, but also could yield better results. The evaluation protocol does not require any parameter adjustment. We are also actively involved in the organization of performance evaluation campaigns for symbol recognition, at a national and international level.

3.2. Characterization and recognition of symbols and signatures

Participants: Philippe Dosch, Bart Lamiroy, Gérald Masini, Jan Rendek, Jean-Pierre Salmon, Salvatore Tabbone, Karl Tombre, Laurent Wendling, Daniel Zuwala.

Symbol recognition consists in localizing and identifying the symbols which are present in a graphical document. Symbols are natural features to use in indexing and retrieval applications. However, the existing recognition methods suffer from a number of weaknesses which make them difficult to use in such a context:

- Most symbol recognition methods work with a known database of reference symbols, or with a learning phase. However, it is easy to imagine browsing applications where the user delineates an arbitrary symbol in a drawing and queries for similar symbols in the database. In such cases, it is impossible to precompile all possible symbols, or to perform time expensive learning procedures.
- Many symbol recognition methods need a preliminary segmentation phase, where candidate regions for symbol recognition are extracted from the image (be it connected components, or subgraphs, or whatever is the most suitable). Thus, we perform segmentation followed by recognition. In some cases, segmentation is easy—of course, character recognition comes to mind, but also other methods where connected components can be used as the basis for segmentation, even if we need some post-processing to disconnect parts touching the graphics.
  Another relatively easy domain is that of schemas and diagrams consisting mainly of symbols and connection lines; it is not surprising that these are the application areas where the best results in symbol recognition have been achieved.
  In many other areas, it is difficult to segment before knowing the symbols, while it remains difficult to recognize the symbols with classical methods without prior segmentation! In such cases, we need to develop noise-resistant methods which are efficient (looking for subgraph isomorphisms on the complete vector set of a large drawing would definitely be the wrong idea) and generic. Thus, there is a need for *segmentation-free symbol recognition* methods or for methods which *perform segmentation while they recognize*.
- A last area where efforts need to be made is the scalability of structural symbol recognition methods. Presently, a number of efficient methods exist for discriminating a symbol among 10 or 20 different models, even if the symbol to be recognized is distorted by noise, other touching graphics, etc. But we don't really know how to scale these structural methods to the recognition of 50, 100 or 500 different symbols. There are both computational complexity issues, and open questions about the power of discrimination of the methods chosen for recognition.

We believe the use of signatures to be a key for some of the challenges just described. Signatures are indeed often used for indexing and retrieval purposes, but most work has concentrated on text-based signatures or image-based signatures. 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 to quickly localize candidate symbols within documents. Each candidate is then recognized using an adaptation of the Radon transform which keeps main geometric transformations usually required for the recognition of symbols. We process directly the grey level document image, in order to improve the recognition steps [20].

Vector-based signatures. It is not always necessary to work directly on the raw image data. Vectorization can yield a set of vector data. In many cases, we also actually directly retrieve vector data from CAD files or similar electronic representations. It is therefore interesting to also use signatures computed directly on these vector data.

Ultimately, our idea is that signatures can be used for symbol spotting and identification of broad hypotheses. This will probably be enough for good retrieval performances, in many cases. If better recognition rates are needed, the preliminary use of signatures can eliminate a number of symbol hypotheses and help segmenting out the candidate region. It can then be followed by classical symbol recognition methods.

In the presence of a large number of symbols, both signatures and structural recognition methods may not be sufficient to discriminate. They could then be used as pre-classification steps, followed by recognition through usual classification methods within the family identified by the signature.

The previously described signature methods contribute, in a sense, to the main goal of document analysis, which is to extract the right level of "meaning" from the document. Be it recognition, indexing or information retrieval, the underlying issue systematically boils down to localization and identification of *objects*. However, once we start talking about the meaning of a document, with the aim of manipulating the underlying semantic concepts, we are implicitly at the crossroads between graphics recognition, information retrieval and knowledge representation. Currently, we only try to focus on the aspects that are related to graphics recognition. Further work will necessarily and progressively integrate models of the other domains. This is why we aim at working on what we call the *intelligent browsing of graphical documents*: Given a set of unstructured documents (scans, PDF, DXF,...) are the most appropriate means of finding information in a reliable and computationally acceptable manner?

Numerous indexing methods exist, with fair recognition rates, but they lack the generic properties required by a real semantic-oriented information retrieval task. The main limitation to generalization is the fact that these indexing methods are based on the same underlying scheme: *context* + *syntax* + *metric* = *semantics*. In other words, information is encoded as the distance of a measurement to the signature of an identified object, given a reasonable number of constraints and prerequisites. While the signature and metric are usually thoroughly studied and documented, the context is most often embedded in the selection of the test images, the application domain and the used algorithms themselves. When dealing with the problem of retrieving semantics from a set of random documents, the previous relationship proves to be non reversible: Given a semantic concept, one may list a number of possible signatures and associated metrics, but there is no way one can decide whether the contextual prerequisites are met (unless, of course, all documents in the set share the same context). The aim of our work on this problem is to come up with a uniform way to take into account this contextual knowledge in the analysis process.

4. Application Domains

Keywords: *Documentation*, *document analysis*, *graphics*, *indexation*, *navigation*.

We are in an era where information is at the core of many industrial strategies. New information-centered services are created, traditional businesses are reoriented towards information services, and new niches appear. This evolution had been predicted by many experts, but they were wrong on one important point: They had foreseen the paperless society, with all-digital information, well structured and logically organized in a uniform way. The truth is very different. The grass-root user, as well as large companies, have a huge amount of information at their disposal, but this information is available in very "poor" formats: Paper documents, or low-level, poorly structured digital formats such as Postscript, PDF or DXF.

The challenge is therefore to convert this poorly structured information into enriched information which can be used within an information system. This does not necessarily mean that it must be completely interpreted and converted to higher-level, semantic-based information. But we need at least to add a layer of indexes and navigation links, to allow for easy browsing and information retrieval.

This is a well known evolution in the document analysis community. Whereas much effort has been made throughout the years to re-engineer documents, *i.e.* to come back to the logical and semantic structures carried by the document, the methods developed to perform this have also been proved to be of interest for the problem of indexing the information for efficient retrieval and browsing. Most effort in this area has been done on textual documents, but the same problem also appears in the presence of graphics-rich documents, such as technical documentation, maps, or schemas. The textual information extracted from these documents must be associated with graphical information: Symbols, lines, areas, etc. The input may be scanned paper documents, but also digital data such as those coming from DXF files.

Traditionally, document image analysis has been a kind of "reverse engineering" activity: Starting with a scanned paper document (the document image), the purpose of analysis has been to retrieve the original characters, words, sentences or structures of the document. In graphics-rich documents, this has led to work on raster-to-vector conversion, also called vectorization (cf. § 3.1.1), and on symbol recognition for various classes of documents: architectural drawings, mathematics, diagrams and schematics, maps, etc.

However, there are a growing number of applications where the need is not for conversion, but for efficient integration of heterogeneous documents into information systems. The problem here is not to have a precise vectorization. It is not either to match potential symbols against a library of existing reference symbols, for the simple reason that such a library does not necessarily exist when you have a large number of diverse documents. The problem is rather to be able to browse these documents, to add a layer of structure, syntax or even semantics on top of the raw data, to build indexes, etc.

There are two major research directions in this area. The first deals with media where there is very little contextual knowledge. Typically, image-based indexing and retrieval methods rely on low-level image features to compute similarity measures. Similarly, video sequences can be indexed into subsequences having a number of homogeneous features. The other direction is that of indexing documents. As a document is a medium made by a person for the explicit purpose of conveying some useful information to other persons, using a language known by all actors, there is much more structure, syntax and semantics to rely on when analyzing a document. Still, the usual document analysis tools are not necessarily efficient enough, nor the most appropriate, for dealing with such indexing purposes. Examples of specific document analysis work for the purpose of indexing and information retrieval include indexing textual documents without performing OCR, just by basing the indexing on similarities or signatures of the connected components, query on the layout structure, or various information spotting techniques.

In our case, we are interested in graphics-rich documents, typically technical documentation containing text, but also a lot of graphics. In this case, the usual text-based indexing and retrieval methods are still of interest, but we also need additional ways of accessing the information conveyed by the documents: Recurring symbols, connections between textual descriptions and drawing parts, etc.

5. Software

5.1. Qgar-Software

Participants: Philippe Dosch, Gérald Masini, Jan Rendek.

5.1.1. Overview

Graphics recognition is a multi-disciplinary domain, involving techniques as heterogeneous as signal processing, image processing, pattern recognition, or computer vision. A research project working in the domain cannot start an application from scratch. It must be able to reuse whole or part of software implemented for previous work, as well as the experience collected at these occasions. The working base constituted in this way allows research projects to be efficiently conducted, by reusing existing material, normalizing program coding, and making ideas and software exchanges easier. Since several years, the QGAR project has devoted much effort to the construction of a software environment including:

- *QgarLib*, a library of C++ classes implementing basic graphics analysis and recognition methods,

- *QgarApps*, an applicative layer, including high-level applications (binarizations, 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.

Any application, either designed separately from the Qgar software or not, can be integrated into the system by simply wrapping it with a predefined C++ class, without recompiling any part of the system itself. The whole system is written in C++ and includes about 50,000 lines of code. A particular attention has been paid to the support of "standard" formats (PBM+, DXF, SVG), high-quality documentation, configuration facilities (using `autoconf/automake`), and support of Unix/Linux and Windows operating systems.

The Qgar system is registered by the French agency for software protection (APP) and may be freely downloaded from its web site (`qgar.org`). It has been used within the frame of several national and international projects.

5.1.2. New results

This year, the work on the Qgar software aimed at improving its robustness and ease of use. This led to a new release, which has been issued on the first of September, 2004, and has also been registered by the APP. A lot of effort has been dedicated to improve the installation procedures, the overall code quality and the documentation of the platform. In the following we present the major achievements concerning the platform installation procedure, QgarGUI, QgarApps, and Qgar Library.

Platform installation procedures. Qgar can now be installed using the widespread RPM package standard. This allows most users to retrieve a binary version of the framework, relieving them from having to rebuild the whole platform from the source code. This packaging has been tested on Linux Mandrake distributions but should work on any other recent Linux distribution. The installation from the source code is still available and is likely to work on any Unix compatible platforms.

QgarGUI. No major changes occurred in the Qgar user interface this year, as the source code was thoroughly reviewed in 2003. However, user feedback along the year helped us correcting minor glitches and improving some functionalities. The most significant change is the better integration of the Qgar applications (QgarApps) by exploiting better their XML description documents [18]. Invocation dialogs are now automatically generated, and an online help about the application is available, directly extracted from their description.

QgarApps. Most of the Qgar Applications have been reviewed, to reflect the changes that occurred in QgarLib, and to improve their robustness [17]. Their documentation has been fully rewritten. Two new applications have been integrated in the core framework, one performing edge detection on a gray-scale image using the Deriche operator, the other performing a binary image degradation using Kanugo's method [31].

QgarLib. All core data structures have been reviewed, and most of them have been refactored using state of the art C++ techniques, such as the heavy use of template programming. In particular, the data structures modeling images and low level graphical primitives have been completely rewritten and a lot of new operations have been added, in particular algorithms for performance evaluation purposes, as our team is involved in this field. This is the case of image degradation methods, like the well-known Kanungo degradation model. These algorithms are intended to be used by our team, as well as for the organization of the various performance evaluation and benchmarking events in which we are involved. Core graphics processing treatments such as connected components extraction have also been refactored. Effort has been made to match the C++ standard notations and data layout. Source files naming and organization now match the standard and the error handling system has been rewritten as an extension of the standard library exception mechanism. The whole library documentation has been reviewed as well, resulting in a better structured and complete versio.

6. New Results

6.1. Feature extraction and segmentation

Participants: Suzanne Collin, Xavier Hilaire, Jean-Pierre Salmon, Salvatore Tabbone, Laurent Wendling.

In the area of vectorization, Xavier Hilaire extended the segmentation method proposed in his PhD thesis [9] to the recognition of discrete conics, and worked on the problem of the calculation of a constraint, minimal discrete surface passing through a simple 3D curve. All three topics are still carried out. Source and binaries for vectorization, developed during his PhD, have been delivered to the FS2i company, which is actually designing a professional vectorization software directly based on his method.

In the area of color images, we have proposed a segmentation method based on a combination of unsupervised clustering and of region growing in the color space. The method requires neither any *a priori* knowledge about the number of regions (or colors) in the image nor any threshold tuning. It is based on a mutli-step strategy, from coarse to fine clustering. The initial seeds for a coarse clustering are provided by a 3D histogram segmentation, and a region growing algorithm based on pixels aggregation then performs a fine segmentation in regions. We have shown that the color regions are correctly identified in a set of various images, but the proposed segmentation strategy is not powerful enough for images including slow color gradations and superimpositions. To improve the quality of the segmentation, we planned to refine the initial detection of valid peaks in the histogram as well as the distance measurement between colors. We are presently studying other clustering strategies, such as clustering by modular neural network and Kohonen network.

Regarding color image binarization, we have proposed a new method based on iterative possibilistic c-mean algorithm, which is adapted by adding a fuzzy entropy criterion to split the membership function in two clusters (background and object) [20]. Such an improvement allows to perform a threshold-free binarization.

In the area of feature extraction, Antoine Tabbone and Laurent Wendling started a collaboration with Isabelle Debled-Renesson, who has defined an incremental and linear algorithm to split digital curves into fuzzy segments with fixed orders [28]. They developed an algorithm for the polygonal approximation of noisy curves from a multi-order analysis of the outline points [20]. Thanks to the notion of fuzzy segment, the algorithm does not require any parameter tuning and it automatically splits a chain of points representing an outline into its most significant components [15][19].

We have also studied an adaptive image-smoothing filter [29] which is more robust regarding different noise levels than existing methods. A master student, Jean-Pierre Salmon, has demonstrated, under the supervision of Salvatore Tabbone, the interest of the use of this filter before a binarization step.

6.2. Characterization and recognition of symbols and signatures

Participants: Philippe Dosch, Salvatore Tabbone, Karl Tombre, Laurent Wendling, Daniel Zuwala.

Our team had previously developed a method for matching complex objects in line-drawings based on angular signature information. This approach preserves fundamental geometric transformations as rotation scale and translation and provides interesting results for discriminating a symbol among around twenty clusters. More discriminant signatures using both the Radon and distance transforms were defined to increase the accuracy of the recognition when the number of binary symbols grows [24] These signatures have also been extended to the retrieval of photometric objects [22][21]. An improvement of this approach consists in defining a multi-resolution descriptor of shapes based on the Radon transform. The key idea is to project a binary shape in the Radon space for different levels of resolution provided by a wavelet decomposition [16]. It gives rise to a representation having a nice behavior with respect to common geometrical transformations.

The study of multi-criteria decision approaches to improve the recognition of particular symbols has also been under consideration these last years. We currently study aggregating methods allowing to improve the recognition when the number of symbols drastically grows [26]. In this context, we have shown the interest of the Choquet integral concept which is able to manage with interactions between criteria. Applications to large databases of symbols is under consideration.

Our team was involved in the organization of the first international contest of symbol recognition, held in Barcelona during GREC'03, in collaboration with the Computer Vision Center of Barcelona [12]. This collaboration continues, as we prepare the second edition of this contest, which will be organized during GREC'05 in Hong Kong. These international contests are the occasion to evaluate symbol recognition methods, in order to determine their performance against various kind of symbols, noise, scalability [25],...In this context, we currently increase the size of our database of symbols, and we search for new metrics and protocols of evaluation. We have also started the design of a web site which will supply all necessary resources for performance evaluation.

7. Contracts and Grants with Industry

7.1. France Télécom R&D

Participants: Bart Lamiroy, Jan Rendek, Karl Tombre.

Our relationship with France Télécom started in 1996, with a research contract on the 3D reconstruction of buildings from their scanned architectural drawings [2]. We then had a new partnership around the problem of indexing technical documentation, through the *Docmining* RNTL project, which was concluded at the beginning of 2004 [10][14]. Since october 2004, we have started a new contract, on the topic of interactive, on-the-fly symbol recognition. Jan Rendek has been hired by France Télécom R&D as a PhD student with a CIFRE contract.

7.2. The FRESH project and Algo'tech

Participants: Jean-Pierre Salmon, Salvatore Tabbone, Karl Tombre.

Algo'tech is a French company based in Biarritz, which develops CAD solutions in electrical design, especially for the aircraft industry. They have a vectorization and document analysis system for electrical wiring drawings. Within the European STREP project FRESH, which should start in December 2004 or January 2005 (final signing of contract is pending at the time of writing), we will contribute to improving this system in the area of symbol recognition for aircraft electrical wiring schemes.

8. Other Grants and Activities

8.1. National actions

8.1.1. ACI Madonne

Participants: Bart Lamiroy, Salvatore Tabbone, Karl Tombre, Laurent Wendling, Daniel Zuwala.

The Madonne research project, supported by the French *ACI Masses de données* program, aims at managing large sets of legacy documents from our cultural heritage. It started at the end of 2003. The participants are the universities of La Rochelle (L3i laboratory), of Rouen (PSI laboratory), of Tours (LI laboratory), of Lyon (LIRIS), of Rennes (IRISA), and the QGAR project. Our contribution to this project is within the areas of document image segmentation and of symbol spotting and recognition. During a DEA student research stay (Thibaud Victoire-Mendoza), we have studied the interest of aggregating common descriptors and we have shown the robustness of Choquet integral calculus for the recognition of broad symbols.

8.1.2. Techno-Vision ÉPEIRES

Participants: Philippe Dosch, Xavier Hilaire, Bart Lamiroy, Gérald Masini, Karl Tombre.

Techno-Vision is a research program proposed both by the French Ministry of Research and the French Ministry of Defense. Its purpose is to fund research projects related to performance evaluation of vision algorithms in computer science. We have proposed a project, called ÉPEIRES (*Évaluation de PErformances de l'Interprétation et de la REconnaissance de Symboles*, performance evaluation of symbol spotting and recognition) together with the universities of Hong Kong (City University of Hong Kong), of La Rochelle (L3i laboratory), of Rouen (PSI laboratory), of Tours (LI laboratory), the DAG team of the Computer Vision Center of Barcelona, the ONE laboratory of France Télécom R&D, and the Algo'Tech company.

The project has been accepted and will last two years, probably starting at the fall of 2004. The QGAR team is the leader of the project. It is in charge of the scientific animation, of the creation of the information system related to the project, and of the creation of the test data that will be used during an evaluation campaign opened to all interested participants.

8.2. International cooperation

8.2.1. CVC Barcelona

In 2004, we also continued our long-lasting scientific cooperation with the Computer Vision Center at Universitat Autonoma de Barcelona. This included a research stay (May 2004–August 2004) in our laboratory of Oriol Ramos, a PhD student, which led to the start of the cooperation between Oriol Ramos, Ernest Valveny (his PhD director in Barcelona), Salvatore Tabbone and Laurent Wendling on the introduction of multi-resolution through a wavelet decomposition in Radon-transform based symbol recognition methods [16].

The ongoing joint work of Ernest Valveny and Philippe Dosch on performance evaluation of symbol recognition was also continued (cf. § 6.2).

8.2.2. University of Auckland, New Zealand

From February to August 2004, Xavier Hilaire was awarded a postdoctoral grant by the French Ministry of Foreign Affairs (*Programme Lavoisier*) to visit the Center for Information Technology and Robotics at the University of Auckland, New Zealand. During this post-doctoral stay, in addition to completing work on vectorization (cf. § 6.1), he designed a method to compute the relative convex hull of a 3D set of points, extending the optimal method known for planar objects only [34]. The resulting algorithm turned out to provide a better lower bound for surface estimation than the approximate method proposed by Yu and Klette [36].

8.2.3. Miscellaneous

Xavier Hilaire is continuing his cooperation with Pr. B. John Oommen, from Ottawa University, Canada, on the definition of a new scheme that globally matches a given vector representation of an image against its ground gruth for the purpose of performance evaluation. The definition of the scheme revealed an interesting problem, not yet investigated in the literature, and conjectured to be NP-hard. A heuristic-based solution to this problem has been proposed, implemented and tested, and appeared to be powerful. We wish to carry on this cooperation, since the necessary formal proofs have now to be stated in order to publish the method.

We initiated contacts with the IFI (*Institut de la Francophonie pour l'Informatique*) at Hanoi, Vietnam, through the research stay of a Master student, Nguyen Thi Oanh, under the supervision of Salvatore Tabbone (June 2004–November 2004) .

Finally, we initiated in 2004 a cooperation with the City University of Hong Kong on the performance evaluation of symbol recognition methods and on the definition of a large database of reference symbols for future international contests.

9. Dissemination

9.1. Animation of scientific community

9.1.1. Journals

Karl Tombre is editor-in-chief of the *International Journal on Document Analysis and Recognition* (Springer-Verlag), advisory editor of *Machine Graphics & Vision*, member of the advisory board for *Electronic Letters on Computer Vision and Image Analysis* and member of the editorial board for ARIMA.

9.1.2. Associations

In August 2004, Karl Tombre was elected first vice-president of IAPR (International Association for Pattern Recognition); previously, he had been secretary of the association since september 2000. In June 2004, he was also elected president of AFRIF, the French association for Pattern Recognition and Image Processing.

9.1.3. Other responsibilities

- Bart Lamiroy is elected to the administration council of INPL, and is the elected representative of the INPL at the CIRIL administration council.
- Karl Tombre is elected to the studies council (CEVU) of INPL.
- Gérald Masini is responsible for the commission of computing facilities users (COMIN) of LORIA.
- Karl Tombre heads the Department for Computer Science of the IAEM Doctoral School, common to the four universities in Lorraine.
- Bart Lamiroy is a member of the *Comité de suivi de l'espace transfert* of the LORIA laboratory. This committee follows and evaluates spin-offs and start-ups created by LORIA members.

9.2. Collaborations within INRIA

At LORIA, we have worked with Isabelle Debled-Rennesson, from the Adage team, on defining a fast polygnoal approximation of digital curves.

Within its activities towards the development of a framework allowing a more semantic level of image querying, QGAR has recently established informal exchanges with the TexMex project-team at IRISA-INRIA Rennes. Both groups have acknowledged several promising research directions in which their complementary know-how could be put to contribution. We have started working together on the definition of a possible topic for joint PhD supervision, in which we would explore the possibilities of combining the TexMex' text analysis and mining tools and QGAR's image analysis libraries in order to mutually enrich and possibly guide the analysis and recognition processes. The goal is to eventually establish an automated text-graphics relationship on as high a semantic level as possible.

9.3. Teaching

- The faculty members of the team teach in their respective universities and departments: École des Mines de Nancy, ESIAL, IUT Charlemagne (Nancy-Verdun), UFR Math-Info of University Nancy 2,...
- Karl Tombre heads the Department for Computer Science of *École des Mines de Nancy*.
- Salvatore Tabbone heads the Department of Computer Science of University Nancy 2.
- Suzanne Collin, Philippe Dosch, Bart Lamiroy, Gérald Masini, and Karl Tombre are members of the recruitment committees in computer science (*commission de spécialistes*) at their universities. Karl Tombre heads that committee for INPL.
- Bart Lamiroy has been one of the major architects and contributors to a new diploma (IPISO), jointly delivered by the *École des Mines de Paris*, *École des Mines de Saint-Étienne*, and *École des Mines de Nancy*, in collaboration with France Télécom. This diploma trains highly qualified engineers at a post-master level in production infrastructures and open system administration for large scale production platforms.

9.4. Conference and workshop committees

- Philippe Dosch is member of the organization committee for the symbol recognition contest at GREC'05 (Hong Kong).
- Salvatore Tabbone was member of the program committees International Workshop on MIVARM'04 (Sherbrooke, Canada) and is member of the program committee for International Document Engineering in ACM-SAC'05 (Santa Fe, New Mexico)
- Karl Tombre was member of the program committees for CARI'04 (Hammamet, Tunisia), CIFED'04 (La Rochelle, France), DAS'04 (Florence, Italy), ICPR'04 (Cambridge, UK), RFIA'04 (Toulouse, France), SPIE DRR11 (San Jose, California), and SSPR'04 (Lisbon, Portugal), and is committee member for CORES'05 (Rydzyna Castle, Poland), GREC'05 (Hong Kong), IbPRIA'05 (Estoril, Portugal), ICDAR'05 (Seoul, Korea), MVA'05 (Tsukuba, Japan), DAS'06 (Nelson, New Zealand), and ICDAR'07 (Curitiba, Brazil).

10. Bibliography

Major publications by the team in recent years

[1] C. Ah-Soon, K. Tombre. *Architectural symbol recognition using a network of constraints*, in "Pattern Recognition Letters", vol. 22, n° 2, February 2001, p. 231–248.

[2] P. Dosch, K. Tombre, C. Ah-Soon, G. Masini. *A complete system for analysis of architectural drawings*, in "International Journal on Document Analysis and Recognition", vol. 3, n° 2, December 2000, p. 102–116.

[3] X. Hilaire, K. Tombre. *Improving the accuracy of skeleton-based vectorization*, in "Graphics recognition – Algorithms and applications", D. Blostein, Y.-B. Kwon (editors)., Lecture Notes in Computer Science, vol. 2390, Springer Verlag, 2002, p. 273–288.

[4] B. Lamiroy, L. Najman. *Scan-to-XML: Using software component algebra for intelligent document generation*, in "Graphics recognition – Algorithms and applications", D. Blostein, Y.-B. Kwon (editors)., Lecture Notes in Computer Science, vol. 2390, Springer Verlag, 2002, p. 211–221.

[5] G. Sánchez, J. Lladós, K. Tombre. *A mean string algorithm to compute the average among a set of 2D shapes*, in "Pattern Recognition", vol. 23, n° 1, January 2002, p. 203–213.

[6] S. Tabbone, L. Wendling, K. Tombre. *Matching of graphical symbols in line-drawing images using angular signature information*, in "International Journal on Document Analysis and Recognition", vol. 6, n° 2, October 2003, p. 115–125.

[7] S. Tabbone, L. Wendling. *Multi-scale binarization of images*.

[8] L. Wendling, S. Tabbone, P. Matsakis. *Fast and robust recognition of orbit and sinus drawings using histograms of forces*, in "Pattern Recongition Letters", vol. 23, n° 14, December 2002, p. 1687–1693.

Doctoral dissertations and Habilitation theses

[9] X. Hilaire. *Segmentation robuste de courbes discrètes 2D et applications à la rétroconversion de documents techniques*, Thèse de doctorat, Institut National Polytechnique de Lorraine, January 2004.

Articles in referred journals and book chapters

[10] E. CLAVIER, G. MASINI, M. DELALANDRE, M. RIGAMONTI, K. TOMBRE, J. GARDES. *DocMining: A cooperative platform for heterogeneous document interpretation according to user-defined scenarios*, in "Graphics Recognition: Recent Advances and Perspectives – Selected papers from GREC'03", J. LLADÓS, Y. B. KWON (editors)., Lecture Notes in Computer Science, vol. 3088, Springer Verlag, 2004, p. 13–24.

[11] P. DOSCH, J. LLADÓS. *Vectorial signatures for symbol discrimination*, in "Graphics recognition: Recent advances and perspectives – Selected papers from GREC'03", J. LLADÓS, Y. B. KWON (editors)., Lecture Notes in Computer Science, vol. 3088, Springer Verlag, 2004, p. 154–165.

[12] E. VALVENY, P. DOSCH. *Symbol recognition contest: A synthesis*, in "Graphics recognition: Recent advances and perspectives – Selected papers from GREC'03", J. LLADÓS, Y. B. KWON (editors)., Lecture Notes in Computer Science, vol. 3088, Springer Verlag, 2004, p. 368–385.

[13] L. WENDLING, S. TABBONE. *A new way to detect arrows in line drawings*, in "IEEE Transactions on PAMI", vol. 26, n° 7, July 2004, p. 935–941.

Publications in Conferences and Workshops

[14] S. ADAM, M. RIGAMONTI, E. CLAVIER, J.-M. OGIER, E. TRUPIN, K. TOMBRE. *DocMining: A document analysis system builder*, in "Document Analysis Systems VI – Proceedings of the 6th IAPR International Workshop on Document Analysis Systems (Florence, Italy)", S. MARINAI, A. DENGEL (editors)., Lecture Notes in Computer Science, vol. 3163, Springer Verlag, September 2004, p. 472–483.

[15] I. DEBLED-RENNESSON, S. TABBONE, L. WENDLING. *Fast polygonal approximation of digital curves*, in "Proceedings of the 17th International Conference on Pattern Recognition (Cambridge, UK)", vol. 1, August 2004, p. 465–468.

[16] O. RAMOS, S. TABBONE, L. WENDLING, E. VALVENY. *Symbol recognition based on a multi-resolution analysis of the Radon Transform*, in "Proceedings of the International Workshop on Image, Video, and Audio Retrieval and Mining (Sherbrooke, Canada)", October 2004.

[17] J. RENDEK, P. DOSCH, G. MASINI, K. TOMBRE. *Principes et mise en œuvre de l'interopérabilité dans le système d'analyse de documents Qgar*, in "Actes du 4eColloque International Francophone sur l'Écrit et le Document (La Rochelle, France)", June 2004, p. 91–96.

[18] J. RENDEK, G. MASINI, P. DOSCH, K. TOMBRE. *The search for genericity in graphics recognition applications: Design issues of the Qgar software system*, in "Document Analysis Systems VI – Proceedings of the 6th IAPR International Workshop on Document Analysis Systems (Florence, Italy)", S. MARINAI, A. DENGEL (editors)., Lecture Notes in Computer Science, vol. 3163, Springer Verlag, September 2004, p. 366–377.

[19] I. RENNESSON-DEBLED, S. TABBONE, L. WENDLING. *Approximation polygonale à partir d'une analyse multi-ordres des points de contour*, in "Actes du 4eColloque International Francophone sur l'Écrit et le Document (La Rochelle, France)", June 2004, p. 171–176.

[20] S. TABBONE, L. WENDLING. *Binarization of color images from an adaptation of possibilistic c-mean algorithm*, in "Proceedings of the 17th International Conference on Pattern Recognition (Cambridge, UK)", vol. 1, August 2004, p. 704–707.

[21] S. TABBONE, L. WENDLING. *Recognition of symbols in grey level line-drawings from an adaptation of the Radon Transform*, in "Proceedings of the 17th International Conference on Pattern Recognition (Cambridge, UK)", vol. 2, August 2004, p. 570–573.

[22] S. TABBONE, L. WENDLING. *Reconnaissance de symboles dans les documents graphiques à niveaux de gris à partir de la Transformée de Radon*, in "Actes du 4eColloque International Francophone sur l'Écrit et le Document (La Rochelle, France)", June 2004, p. 45–50.

[23] S. TABBONE, L. WENDLING. *Retrieving images by content from strong relational graph matching*, in "Proceedings of the 17th International Conference on Pattern Recognition (Cambridge, UK)", vol. 2, August 2004, p. 951–954.

[24] S. TABBONE, L. WENDLING, D. ZUWALA. *A hybrid approach to detect graphical symbols in documents*, in "Document Analysis Systems VI – Proceedings of the 6th IAPR International Workshop on Document Analysis Systems (Florence, Italy)", S. MARINAI, A. DENGEL (editors)., Lecture Notes in Computer Science, vol. 3163, September 2004, p. 342–353.

[25] E. VALVENY, P. DOSCH. *Performance evaluation of symbol recognition*, in "Document Analysis Systems VI – Proceedings of the 6th IAPR International Workshop on Document Analysis Systems (Florence, Italy)", S. MARINAI, A. DENGEL (editors)., Lecture Notes in Computer Science, vol. 3163, Springer Verlag, September 2004, p. 354–365.

[26] L. WENDLING, S. TABBONE. *Détection de flèches dans des documents techniques à partir d'une agrégation de critères géométriques*, in "Actes du 14eCongrès de Reconnaissance des Formes et Intelligence Artificielle (Toulouse, France)", vol. 3, January 2004.

Miscellaneous

[27] L. WENDLING. *Relations spatiales directionnelles et reconnaissance des formes*, January 2004, Seminar at the Centre de Données Astronomiques, Strasbourg.

Bibliography in notes

[28] I. DEBLED-RENNESSON, J.-L. RÉMY, J. ROUYER-DEGLI. *Segmentation of discrete curves into fuzzy segments*, in "Electronic Notes in Discrete Mathematics", A. DEL LUNGO, V. DI GESÙ, A. KUBA (editors)., vol. 12, Elsevier, 2003.

[29] L. FAN, L. FAN, C. TAN. *Adaptive image-smoothing using a coplanar matrix and its application to document image binarization*, in "International Journal on Document Analysis and Recognition", vol. 5, n° 2–3, April 2003, p. 88–101.

[30] X. HILAIRE. *A matching scheme to enhance performance evaluation of raster-to-vector conversion systems*, in "Proceedings of the 7th International Conference on Document Analysis and Recognition, Edinburgh

(Scotland, UK)", August 2003, p. 629–633.

[31] T. KANUNGO, R. M. HARALICK, H. S. BAIRD, W. STUEZLE, D. MADIGAN. *A statistical, nonparametric methodology for document degradation model validation*, in "IEEE Transactions on PAMI", vol. 22, n° 11, November 2000, p. 1209–1223.

[32] K. TOMBRE, C. AH-SOON, P. DOSCH, G. MASINI, S. TABBONE. *Stable and robust vectorization: How to make the right choices*, in "Graphics recognition – Recent advances", A. K. CHHABRA, D. DORI (editors)., Lecture Notes in Computer Science, vol. 1941, Springer Verlag, September 2000, p. 3–18.

[33] K. TOMBRE, S. TABBONE, L. PÉLISSIER, B. LAMIROY, P. DOSCH. *Text/graphics separation revisited*, in "Proceedings of the 5th International Workshop on Document Analysis Systems (Princeton, New Jersey, USA)", D. LOPRESTI, J. HU, R. KASHI (editors)., Lecture Notes in Computer Science, vol. 2423, Springer Verlag, August 2002, p. 200–211.

[34] G. T. TOUSSAINT. *An optimal algorithm for computing the relative convex hull of a set of points in a polygon*, in "Signal processing III: Theories and applications – Proceedings of the 3rd European Signal Processing Conference", 1986, p. 853–856.

[35] Ø. D. TRIER, A. K. JAIN. *Goal-directed evaluation of binarization methods*, in "IEEE Transactions on PAMI", vol. 17, n° 12, December 1995, p. 1191–1201.

[36] L. YU, R. KLETTE. *An approximative calculation of relative convex hull for surface area estimation of 3D digital objects*, in "Proceedings of the 16th International Conference on Pattern Recognition (Québec, Canada)", vol. 1, 2002, p. 131–134.