Research activities in Pattern Recognition, Image Analysis and MUltimedia Systems @ DIETI

PRIAMUS Group

Dipartimento di Ingegneria Elettrica e delle Teconologie dell'Informazione (DIETI)
University of Naples Federico II
Via Claudio 21, Naples, Italy.
carlosan@unina.it

This document describes some of the recent research activities carried out by the members of the **PRIAMUS** (Pattern Recognition Image Analysis and MUltimedia Systems) group @ DIETI (University of Naples Federico II) in the fields of:

- Biomedical Image Analysis and Interpretation,
- Digital Image Forensics,
- Multimedia Systems.

1 Biomedical Image Analysis and Interpretation

Dynamic Contrast Enhanced-Magnetic Resonance Imaging (DCE-MRI) has demonstrated in recent years a great potential in screening of high-risk women for breast cancer, in staging newly diagnosed patients and in assessing therapy effects.

In this field, we have developed a fully automated Computer Aided Detection (CAD) system [1] for suspicious lesion detection in DCE-MRI to support radiologists during patient image analysis. The proposed method is based on a Support Vector Machine trained with dynamic features, extracted, after a suitable pre-processing of the image, from an area pre-selected by using a pixel-based approach. This research activity has been carried out together with R. Fusco and A. Petrillo of the National Cancer Institute of Naples Pascale Foundation.

The segmentation of DCE-MRI images is made harder by the dynamical characteristics of the DCE-MRI examinations of soft tissues: patient movements may affect the voxel-by-voxel dynamical analysis. To remove (or at least reduce) such motion artefacts we have also considered some image registration techniques, selecting the one that best suits the dynamics of the breast tissue. To perform the latter task, we have proposed a novel model-based measure for quality evaluation of image registration techniques in DCE-MRI by means of a well-known compartmental model of blood plasma and of the extravascular extracellular space (EES) for tumour tissue (the so-called Tofts model) [2].

Our results showed that the ranking of different image registration techniques obtained by means of the proposed quality assessment measure is in agreement

with the ranking of the results achieved by our CAD segmentation system when using the same image registration techniques. This proves that our measure, differently from traditional similarity measures, can correctly evaluate different image registration techniques in DCE-MRI.

Finally, we proposed a framework for advanced medical image remote analysis in a secure and versatile client-server environment at a low cost. We also presented an implementation of this framework, where OsiriX, a wide-spread medical image analysis software, is capable to perform remote image processing in a secure way [3].

2 Digital Image Forensics

Digital sources are more and more frequently used to make important decisions. This is especially true in the forensic field, where images can be used, for example, to describe the scene of a crime or to define responsibilities in road accidents. However, thanks to more and more sophisticated editing tools, it is possible to easily modify photos leaving little or no traces of manipulation.

In [4] we addressed the problem of detecting and localizing forgeries by means of the photo-response non-uniformity (PRNU) noise, a sort of camera fingerprint, arising from tiny imperfections in the silicon wafer used to manufacture the imaging sensor. In particular, we proposed a new appproach by means of a suitable Markov random field prior to model the strong spatial dependences of the source, and take decisions jointly on the whole image rather than individually for each pixel. Modern convex optimization techniques are then adopted to achieve a globally optimal solution and the PRNU estimation is improved by resorting to nonlocal denoising. A drawback of this approach is the fact that the PRNU pattern is a very weak signal, hence it can be reliably detected only by jointly processing a large number of image samples, reducing the algorithm's ability to reveal small forgeries.

To improve resolution in [5] we proposed a strategy based on a spatially adaptive filtering technique, with weights computed over a suitable pilot image. Experiments prove that the proposed algorithm provides much better results on critical small-size forgeries, with a negligible increase in complexity.

PRNU is especially used for source camera identification and in this context we have investigated the robustness of the triangle test [6], a recently proposed approach that try to take countermeasures to a possible attack made by an expert adversary. In fact it is not difficult to estimate a camera PRNU using images of the same camera found on the web or stolen from a PC. Then, the estimated PRNU can be superimposed on a target image coming from a different camera, eliciting a false identification.

In [7] we show that, by properly choosing the strength of the inserted fingerprint, the attacker can significantly improve the chances to undermine the triangle test. In addition, we propose a two-step algorithm that the attacker can use to estimate the best value of the fingerprint strength, based exclusively on the knowledge of the stolen images.

Another challenging forensic problem is the ability to detect the liveness of fingerprint images. In fact, biometric systems are relatively vulnerable and can be easily fooled by fake fingerprints, reproduced on simple molds made of materials such as silicone, Play-Doh, clay or gelatin.

In [8] we proposed wavelet-based features for the liveness detection task. In fact, wavelets are especially good at catching the short-time transient or localized changes in signals, which are highly discriminative features. This property is further emphasized by computing co-occurrences of wavelet residuals, in the same or different wavelet subbands. To further improve the discrimination capability of the classification process, in [9] we constructed a local descriptor by analyzing the image both in the spatial and in the frequency domain, in order to extract information on the local amplitude contrast, and on the local phase of some selected transform coefficients. These two pieces of information are used to generate a bi-dimensional contrast-phase histogram, used as feature vector associated with the image. After an appropriate feature selection, a properly trained linear-kernel SVM classifier makes the final decision.

Both these research activities have been carried out in collaboration with the members (D. Cozzolino, D. Gragnaniello, G. Poggi and L. Verdoliva) of the GRIP group @ DIETI.

3 Multimedia Systems

Wtihin the Multimedia Systems research field, we first deal with the problem of automatic event detection for the last generation video-surveillance applications. Our solution is based on the analysis of different multimedia streams (i.e. video and audio data) by means of the combined use of *Computer Vision* facilities together with novel *Probabilistic Reasoning* and *Pattern Recognition* techniques.

In such a context, several collaborations with the University of Maryland (VS Subrhamanian) and University of Calabria (A. Pugliese and C. Molinaro) have been established since many years.

More recently, the research activities results have been exploited for the development of a video-surveillance) prototype - named PADUA (Parallel Architecture to Detect Unexplained Activities) - able to recognize *unexplained activities* using a parallel computing infrastructure [10].

In particular in the proposed framework, we assume that there is a set of known activity models (both harmless and harmful) and a log of time-stamped observations. We define a part of the log to represent an unexplained situation when none of the known activity models can explain such a part with a score exceeding a user-specified threshold. We represent activities via the notion of a *Probabilistic Penalty Graph* (PPG) and show that a set of PPGs can be combined into one Super-PPG, introducing an index structure for the fast access. Given a compute cluster of (K +1) nodes (one of which is a master node), we show how to split a Super-PPG into K subgraphs that can be autonomously processed by K compute nodes. Eventually, we provide algorithms for the individual compute nodes to ensure seamless handoffs that maximally leverage parallelism.

PADUA is domain-independent and can be applied to many domains (perhaps with some specialization). We conducted detailed experiments with PADUA on two real-world datasets. First, we tested PADUA on the ITEA CANDELA video surveillance dataset. Second, we tested PADUA on network traffic data appropriate for cybersecurity applications. PADUA scales extremely well with the number of processors and significantly outperforms past work both in accuracy and time. Thus, PADUA represents the first parallel architecture and algorithms for identifying unexplained situations in observation data and - in addition to high accuracy - can scale well.

We also face the issue of personalized multimedia *visiting paths* generation for Cultural Heritage applications. Our proposal combines in a novel manner *Multimedia Content-Based Retrieval* facilities, *Co-Clustering* techniques and *Context-Aware Recommendation* services using data coming from the most common Big Data sources (social networks, multimedia repositories, sensor networks, etc.) [11–13].

The proposed strategy addresses several drawbacks of state-of-the-art approaches:

- analyzing in a separate way low and high level information of multimedia data, since both contribute to determine the utility of an object in the recommendation process;
- exploiting system logs to implicitly determine information about users and the related community, considering their browsing sessions as a sort of ratings;
- considering as relevant content for the recommendation the features of the object that a user is interested in (e.g. the item user is watching);
- exploiting user preferences and other context information (e.g. user location) to perform a prefiltering of the candidate objects for recommendation;
- arranging the obtained recommendations in dynamic visiting paths that take into account possibile changes in user needs and in the surrounded environment.

In such a context, several collaborations with the University of Turin (M.L. Sapino), University of Bologna (I. Bartolini, M. Patella) and George Mason University (M. Albanese) have been established. As result, we developed a touristic multimedia guide prototype able to suggest personalized visiting paths to users both for indoor (e.g. museum, library) and outdoor (e.g. archeological ruins, old town center) environments.

Finally, we are recently working - within the *Smart-Health* PON project - on the design of an exergaming platform based on Virtual Reality technologies and Pattern Recognition techniques and capable of supporting the assisted diagnosis and the related physical therapy for different kinds of pathologies.

References

1. Marrone, S., Piantadosi, G., Fusco, R., Petrillo, A., Sansone, M., Sansone, C.: Automatic lesion detection in breast dce-mri. In: International Conference on Image Analysis and Processing (ICIAP). (2013) 359–368
2. Marrone, S., Piantadosi, G., Fusco, R., Petrillo, A., Sansone, M., Sansone, C.: A novel model-based measure for quality evaluation of image registration techniques in dce-mri. In: IEEE 27th International Symposium on Computer-Based Medical Systems (CBMS). (2014)
3. Piantadosi, G., Marrone, S., Sansone, M., Sansone, C.: A secure osirix plug-in for detecting suspicious lesions in breast dce-mri. In: 13th International Conference on Algorithms and Architectures for Parallel Processing (ICA3PP). (2013) 217–224
4. G.Chierchia, G.Poggi, C.Sansone, L.Verdoliva: A bayesian-mrf approach for prnu-based image forgery detection. IEEE Transactions on Information Forensics and Security **9**(4) (april 2014) 554–567
5. G.Chierchia, D.Cozzolino, G.Poggi, C.Sansone, L.Verdoliva: Guided filtering for prnu-based localization of small-size image forgeries. In: IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). (2014)
6. Goljan, M., Fridrich, J., Chen, M.: Defending against fingerprint-copy attack in sensor-based camera identification. IEEE Transactions on Information Forensics and Security **6**(1) (March 2011) 227–236
7. Marra, F., Roli, F., Cozzolino, D., Sansone, C., Verdoliva, L.: Attacking the triangle test in sensor-based camera identification. In: IEEE International Conference on Image Processing (ICIP). (2014)
8. D.Gragnaniello, G.Poggi, C.Sansone, L.Verdoliva: A wavelet-markov local descriptor for detecting fake fingerprints. Electronics Letters **50**(6) (march 2014) 439–441
9. D.Gragnaniello, G.Poggi, C.Sansone, L.Verdoliva: Local contrast phase descriptor for fingerprint liveness detection. Pattern Recognition (submitted, 2014)
10. Molinaro, C., Moscato, V., Picariello, A., Pugliese, A., Rullo, A., Subrahmanian, V.: Padua: Parallel architecture to detect unexplained activities. ACM Transactions on Internet Technology (TOIT), Special Issue on Event Detection (to appear 2014)
11. Bartolini, I., Moscato, V., Pensa, R., Penta, A., Picariello, A., Sansone, C., Sapino, M.L.: Recommending multimedia visiting paths in cultural heritage applications. Multimedia Tools and Applications (MTAP), Special Issue on Cultural Heritage (to appear 2014)
12. Bartolini, I., Moscato, V., Pensa, R., Penta, A., Picariello, A., Sansone, C., Sapino, M.L.: Recommending multimedia objects in cultural heritage applications. In: International Conference on Image Analysis and Processing (Workshops). (2013) 257–267
13. Bartolini, I., Moscato, V., Pensa, R., Penta, A., Picariello, A., Sansone, C., Sapino, M.L.: A framework for recommending multimedia cultural visiting paths. In: SEBD Workshop. (2014)