Intelligent System for Computer-assisted Clinical Cancer Image Analysis

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Abstract: We present CaDiS - a new multimedia medical workstation, which helps early and precise diagnosis and treatment of cervical cancer. The workstation is developed with the close participation of medical staff of Novosibirsk Clinical Center. CaDiS is an advanced tool for medical image recognition, designed on the basis of new algorithms for medical image analysis. It is under intensive development and will include history of illness, analysis and prediction, based on perceptual and conceptual semantics. The detection accuracy of the proposed system has reached to 91%, providing thus an indication that such intelligent schemes could be used as a supplementary diagnostic tool in cervical cancer detection.

Key words: Computer aided diagnosis, neural networks, multimedia medical workstation, medical image analysis, intelligent interface.

1 Introduction

In many clinical scenarios, images from several modalities may be acquired and the diagnostic task is to mentally combine or fuse this information to draw useful clinical conclusions[Ce99]. In particular, in oncology, physicians work on different image modalities, none of which contains the complete information about the cancer disease. Our first objective was to develop a new tool to support conceptualization and mental combination of all this data. Our research efforts have lead to the design of a new application - CaDiS workstation. CaDiS incorporates multimedia capabilities as image acquisition, reproduction and storage for cervical cancer images. It also handles relevant information about the patient and the study. The paper presents the image description methodology, intensively applied in the development of CaDiS and outlines the main functionalities of the workstation, making it an advanced tool for oncology diagnosis.

The paper is organized as follows: section 2 describes the global system and its main characteristics, section 3 goes deeper in the understanding of each underlying module, section 4 is devoted to the image analysis module, section 5 illustrates the interest of the system in a real case study, which is the cells counting in region of image. Section 6 concludes and indicates future work.

2 System Overview

The major components of the physical architecture are presented in fig. 1.

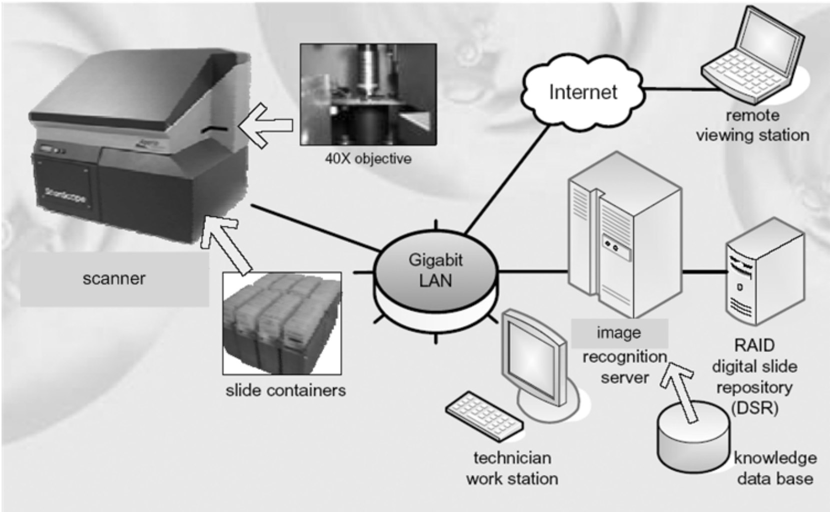

Figure 1: The physical architecture

Basically, the system is composed of computers connected together through a typical fast Ethernet network (100 Mb/s). The scanner are plugged either on an acquisition card on a PC or directly on the local network switch . A human computer interface and a storage space are also plugged on this system. The main advantage of such an architecture is its flexibility. Future needs in computing power will be simply addressed by adding a PC in the cluster. Fig. 2 shows a screen shot of the graphical user interface (GUI). From an end-user point of view, the GUI is one of the most important modules. It must be very easy to use but efficient.

The logical architecture has been designed in a modular way to allow a fair resource allocation over the cluster. In its implementation, each software module is dedicated to a specific task (e.g., coding, network management,...). The various treatment modules are distributed on the PC units according to configuration set-up parameters. In these parameters, the operator will define the architecture of the distributed system and moreover, he will be able to customize the action of the different modules (e.g., the vision processing units require a lot of parameters). A master process will be assigned the task of communicating the configurations parameters to all the PC units. Changes in the distribution of the different tasks between the units could be performed dynamically during the run-time of the system. The robustness of the overall system is provided by the logical architecture. It manages the various problems that can arise: a network packet loss, a network transmission interruption, a hard drive stopping, a frame loss in the image acquisition process, etc. A powerful data management handles the distribution of information along the whole

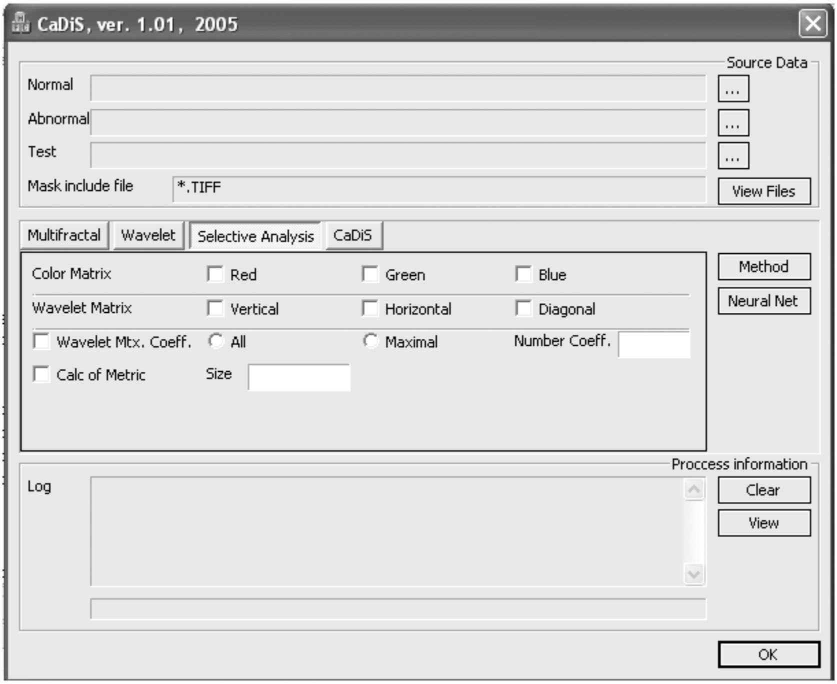

Figure 2: A view of a GUI of the system

system.

The systems basic structure for data management between modules handles the concurrent access for sharing information for multiple producers and consumers, the network communication (TCP/IP) for multiple instances of the data (compression handling if necessary), the dynamic connection and access to the stream, the buffer to absorb peak of processing, the implicit conversion of data (e.g. images from RGB to YUV), the propagation of consumers needs to producers (e.g. if no module uses a segmentation result, the segmentation module will be advised not to produce it), the monitoring of the streams (performance, rate).

3 Description of System Components

The various modules of the software part of the system are explained hereunder. We explain the acquisition, the network and the storage modules. Section 4 will describe the image analysis module.

3.1 Acquisition

CaDiS system accepts Pap-stained monolayer preparations. It uses an automated microscope, which able to hold 40 slides. The slides are positioned onto the stage of the microscope where focussing and stage movement are computer controlled. Screening of a single slide is accomplished using a camera that is software controlled to a maximum of 3 000 x 2 000 pixels. In 24 hours, 300 slides may be screened by a single machine.

3.2 Networking

Having a distributed system implies an efficient use of the bandwidth. We have seen that the various modules related to an image input can be dispatched on several computers. For example, the system can perform the acquisition on computer A, the storage on computer B and the display on computer C. We have chosen a multicasting technique to solve the bandwidth occupation problem. Each image source has an associated multicast channel. This multicast channel is accessed through an UDP connection by every module that needs the image input. Since UDP does not offer a quality of service (QoS), we have developed a protocol that can detect when a transmission failure occurs. But if we assume to use the system on a dedicated network, there are only few occurrences of transmission failures. We guarantee small delays because the network load is controlled in order to avoid buffer queuing. The decrease of the delay could be improved by passing through the ISO networks layers and use IP packets with the knowledge of its implementation on the Ethernet layer. This delay is small enough to be imperceptible for the user (i.e. less than 150 ms).

3.3 Storage

The storage module has to deal with the enormous quantity of data to store. It must allow a 24-hours per day storage. This module has two levels: level 0 is a classical storage process with the data compress technology. Level 1 is an intelligent storage process. It stores only interesting events that the user has defined. This level saves tremendous storage space. Moreover, it allows a fast search to retrieve a stored sequence.

4 Image Analysis Module

The architecture of the vision part of the system is divided in three main levels of computation that achieve the interpretation: Image level (image filtering, background evaluation and segmentation), Blob level (description, blobs filtering, matching, recognition), event level (finite state machine, performance evaluations). We will only describe here the image and object levels (Fig. 3) as the event level is quite application dependant.

4.1 Pre-processing and segmentation

After acquisition, the current image is filtered in the pixel domain to decrease the spatial high-frequency noise. Many reference image models could be used for representing the backgrounds as they are implemented in the system. However, these algorithms should satisfy the non-periodic processing framework of the system. Thus the segmentation process is divided in two stages: update and estimation. As shown in Fig. 3, the segmentation is fully configurable as one can choose between three types of background models (e.g. mixture of Gaussian [Ja02], low pass temporal recursive filter[Ge03], temporal median filter) and foreground extraction processes. For the application shown in section 5, the system will only use the mixture of Gaussians background, as it is quite robust to common noises. The update stage will revise the mixture of Gaussian for each pixel background, and the estimation stage will extract the a priori foreground, filter it via morphology processing and then label objects[HB90].

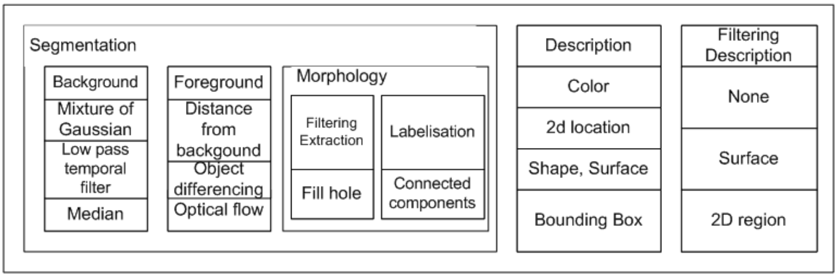

Figure 3: Image and description level: Segmentation and Description

4.2 Blobs description and filtering

The aim of blobs description and filtering is to make the interface between segmentation and recognition and simplify the information. The description process translates image data into a symbolic representation (i.e. descriptors)[De90]. The goal is to reduce the amount of information to what is necessary for the recognition module. The description process calculates, from the image and the segmentation results the k different observed features of a blob i: bounding box, mean RGB color, 2D visual surface, inertial axis of blob shape, extreme points of the shape, etc. At this point, there is another filtering process to remove small blobs, blobs in an area of the image not considered, etc.

4.3 Recognition algorithm

The recognition part of the system is flexible and fully parametrical. The set-up should be done for a trade-off between computational resources, needs of robustness and segmentation behavior. It is divided in three steps that follow a straightforward approach: estimation, cost matrix computation, matching decisions[FK71]. Note that there are multiple predictions and cost matrixes when the last matching decision is not unique, and there are only multiple matching decisions for some matching algorithms.

5 Conclusion and Future Work

In this paper, we have proposed an original approach for a cancer images recognition platform[BK05] that can provide the flexibility needed by researchers and that can meet the strong efficiency requirements of industrial applications. This system is presented as being very efficient and it has been validated on various uses. We are currently investigating new feature modules, e.g. better segmentation and data analysis methods. Moreover, other extensions and improvements will be made on the global system. Future works will also integrate security connection like VPN to communicate parameters, results and logs over long distance.

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References

[BK05] Bondarenko, A.N., Katsuk A.V., Cervical pre-cancer detection using multifractal and wavelet analysis, 2-d IASTED International Multi-Conference on Automation, Control and Information Technology, Novosibirsk, Russia, June 20-24, 2005; pp. 240-245

[Ja02] Jaynes C. et al, An Open Development Environment for Evaluation of Video Surveillance Systems, IEEE Workshop on Performance Analysis of Video Surveillance and Tracking (PETS'2002), In conjunction with ECCV, June 2002.

[Ge03] Georis B. et al., IP-Distributed computer-aided videosurveillance system, Intelligent Distributed Surveillance Systems Workshop, London, UK, February 26, 2003.

[De90] Deriche, R., Fast Algorithms For Low-Level Vision. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 1990, pp. 78-87

[Ce99] Carson C., et al, Blobworld: A System for Region-based Image Indexing and Retrieval, In Proceedings of the 3rd International Conference on Visual Information Systems, 1999.

[FK71] Fukunaga, K., Kessell, D.L., Estimation Of Classification Error. IEEE Transactions on Computers, 1971, pp. 1521-1527

[HB90] Haddon J.F., Boyce J.F., Image segmentation by unifying region and boundary information, IEEE Transactions on Pattern Analysis and Machine Intelligence, 1990, pp 929-948.