# PULAB
## *Computational-Intelligence Aided Management, Diagnosis, Teleassistance and e-Learning of Pressure Ulcers*

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Abstract: The pressure ulcer is a clinical pathology with high prevalence rates, which involve high costs for the Health systems. The health promotion carried on these lesions, as well as the prevention, suitable evaluation and correct treatment, have become effective indicators of the quality of health assistance. PULAB (Pressure Ulcer LABoratory) is a computational tool that enables remote management, diagnosis and monitoring of pressure ulcers, which include digital images of the wounds. This teleassistance software gives support to the collaborative work of multiple clinical experts to concurrently evaluate the pressure ulcers by reaching consensus on each particular case, based on the effective analysis of automatically segmented and tissue-labeled images of the wounds. In the current phase of our research project an e-learning module for pressure ulcer diagnosis education is being designed, which will turn this software into a valuable pedagogical tool for pressure-ulcer-management training for undergraduate students and professional clinicians.

## 1 INTRODUCTION

The European Pressure Ulcer Advisory Panel (EPUAP) defines a pressure ulcer (PU) as an area of localized damage to the skin or its underlying tissue caused by pressure, shear, friction or a combination of these factors (EPUAP, 1999; Gawlitta et *al.*, 2007; Tsuji et *al.*, 2005). The prevention, care and treatment of the PU pathology involve high costs for private or state health systems and have important consequences for the health of the population, especially for elderly citizens. PU prevalence rates vary significantly among different environments of health assistance. Several studies carried on populations of elderly patients with home assistance have shown prevalence rates that fluctuate between 12.7% and 15.1% (Bours et *al.*, 1999; Woodbury & Houghton, 2004); on the other hand, in acute units the prevalence data found are even more variable and range from 7% to 33% of the population analyzed (Gunningberg, 2004; Melotti et *al.*, 2003; Tannen et *al.*, 2004); finally, higher prevalence rates were observed in studies carried out on units of long-term hospitalized patients (Woodbury & Houghton, 2004; Horn et al., 2002).

The precise evaluation of PUs is a fundamental task for diagnosis, monitoring of healing evolution and making decisions on care and pharmacological treatment interventions. Precise evaluation and monitoring of the PU could be achieved whether all the tissues present in the wound or surrounding areas are accurately measured and precisely registered (see (Edsberg, 2007) for a complete and systematic review of PU histology). Following this strategy, in (Veredas et *al.*, 2010) the same authors of this current paper presented a computational tool for automatic segmentation and tissue detection on PU digital images. This software was based on a hybrid system which uses Computational Intelligence (CI) techniques, neural networks and Bayesian classifiers to be precise, to automatically classify significant


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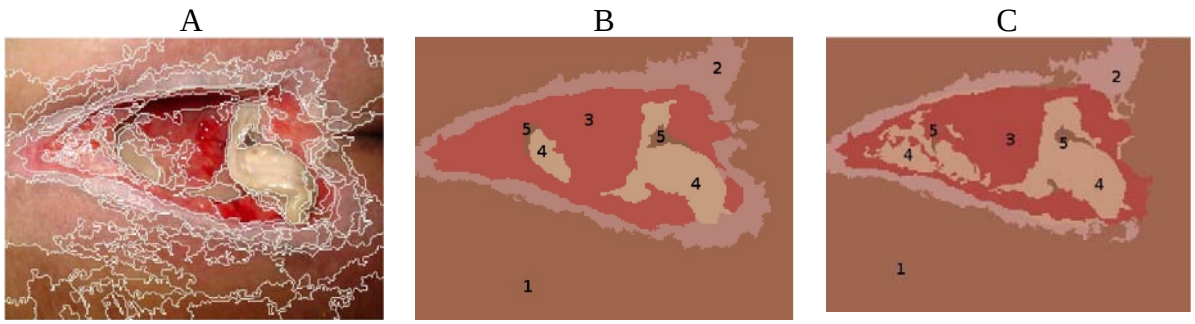


Figure 1: Automatic tissue recognition on a PU digital image. Picture A shows the results from the automatic region segmentation of a PU image using the mean-shift procedure and region growing. For B, a group of expert clinicians have labeled each one of the regions resulting from the segmented image in A. Picture C shows the automatic labeling done by the CI system based on neural networks, Bayesian classifiers and heuristics. The tissues shown in B and C have been labeled with a number that represents: 1: skin; 2: healing tissue; 3: granulation tissue; 4: devitalized tissue; 5: necrotic tissue. Regions labeled with a same tissue type have been given a same pseudocolor for the sake of clarity. *(Figures included here with permission of* (Veredas et al., 2010)*).*

regions from segmented wound images, obtaining high precision rates as results.

These CI techniques for automatic tissue detection have been incorporated into the core of PULAB tool, which has been designed for the registering, monitoring, the collaborative expert evaluation, teleassistance and continuing education on PUs. At present, PULAB tool is being enriched with the incorporation of a new e-learning module designed for education on PU diagnosis for undergraduate students as well as for continuing education for professional clinicians. This e-learning software will be validated during the next few months by using it in education and competence acquisition of Nursing university students.

## 2 TISSUE RECOGNITION

PULAB tool for management, collaborative evaluation and teleassisance of PUs is internally composed of an integrated core based on the CI strategies and machine learning techniques that have been developed by the same authors of this current paper. This software enables automatic segmentation and precise tissue detection on PU images (Veredas et *al.*, 2010). Image segmentation on this PU images is arranged by means of the mean-shift segmentation method (Comaniciu & Meer, 2002). In figure 1-A, a typical PU image has been segmented by means of the mean-shift procedure.

Table 1: Efficiency rates from automatic tissue detection on 113 PU images. *(Data obtained, with permission, from Table VI in* (Veredas et al., 2010)*).*

| | Sensitivity | Speci-ficity | Accuracy |
|---|---|---|---|
| Necrotic | 86.3 % | 98.5 % | 98.2 % |
| Devitalized | 67.4 % | 95.7 % | 93.3 % |
| Granulation | 82.7 % | 94.7 % | 92.6 % |
| Healing | 59.9 % | 91.1 % | 85.4 % |
| Skin | 85.2 % | 91.0 % | 87.9% |
| GLOBAL | 78.7 % | 94.7 % | 91.5 % |

In the table 1, efficiency rates are shown from the results obtained in the automatic classification of the tissues present in a set of 113 testing PU images (not previously "seen" by the machine learning system). As can be deduced by observing this table, the automatic classification system based on CI techniques and used by PULAB for PU evaluation shows high efficiency rates, not only in the classification of each particular tissue type, but also in global terms.

## 3 THE PULAB TOOL

PULAB is a multiuser teleassistance tool that makes possible the recording of clinical data and the collaborative evaluation of PUs. This software tool has the main purpose of increasing the accuracy of the diagnosis and the effectiveness of care and treatment interventions. Moreover, this software enables the management of each particular wound case by means of registering digital pictures in the system and storing contextual clinical data

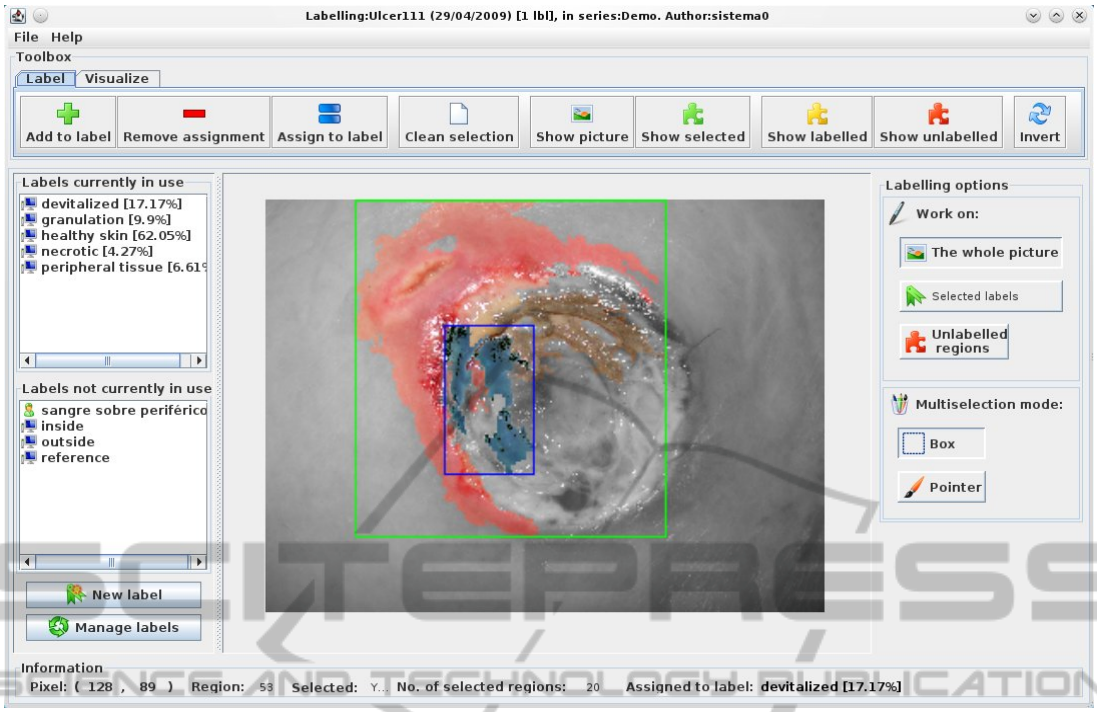


Figure 2: PULAB's graphical user interface for manual tissue labeling of a registered PU image.

associated with the PU. The system's users, i.e. the clinicians and health professionals in general, can also use PULAB to manage PU series of wounds grouped by different criteria. Once a PU image has been uploaded to the system (with its clinical associated information enclosed), it is immediately processed by the CI subsystem for region segmentation and automatic tissue detection. From that moment on, the user counts on an initial automatic diagnosis and can look up this automatic evaluation done by the system to do manual adjustments on the tissue classification in order to get a final refined diagnosis. These manual improvements on the tissue classification are done with the aid of a friendly graphical user interface that facilitates the task of region-of-interest selection and tissue identification. Finally, the system provides a useful module to efficiently create and manage collaborative work groups of clinicians who can share their opinions and reach agreements on diagnosis of each particular PU case.

PULAB has been designed following a methodology that is based on a client/server model. PULAB's user interface has been developed in Java and is accessible at the *url* https://itaca.lcc.uma.es/ulceras/pulab/launch.jnlp by means of *Java Web Star*®.

The main modules of PULAB are the following:

- User-authentication and session-control module: provides the control of authenticated users, giving the basis for the management of collaborative work groups.
- PU-series module: makes possible the creation and management of series of PUs grouped by heterogeneous criteria (temporal series of a same patient, grouping by grade or presence of different tissue types, grouping by anatomic location, etc.).
- Collaborative-group module: enables the management of groups of users to share PU series, evaluations, diagnosis or decisions on interventions on the wounds.
- System-record module: provides the management and controls notification of actions launched by the systems, such as registrations and deletions of users, groups, series, etc.; termination of processes of image segmentation or tissue detection by the system, etc.
- PU-visualization module: enables the interaction between the user and the system to visualize the PU images and navigate on the segmented regions and classified tissues.
- Labeling module: provides the tools for manual labeling of the regions resulting from the automatic segmentation of the images; this module supplies the user with the necessary

tools to manually classify, in a easy and friendly manner, the segmented regions into the different tissue types (see the figure 2 for an screenshot of the user's interface of the labeling module on an example of a real PU image).

## 3 DIAGNOSIS E-LEARNING

An effective strategy to reduce the use of pharmacological treatments of not-validated benefits and to homogenize clinical interventions could be to improve the education of both Health undergraduate students and professional clinicians. Traditional education on PU pathology suffers from some weaknesses that could put the efficacy of the learning process at risk: on one hand, students behave usually as merely passive actors during the learning process, and their interests and motivations are usually very poor; on the other hand, in clinical practice, a high variability in the learning procedure is usually generated. Considering these two issues above, and as a strategy to improve the learning process and also guaranty its efficacy and homogeneity, the current development of PULAB tool has the main objective of introducing Information and Communication Technologies (ICT) to education on PUs for Health undergraduate students and professionals (i.e. continuing education).

Very few studies exist on evaluating educational experiences with ICT-based tools in the specific field of education on PUs for professional clinicians. However, some authors conclude that the development of tools that make e-learning possible increases the efficacy of the educational processes since it reduces the time consumed in the learning process and improves the accessibility of the student to that learning (Bolwell, 1993). Furthermore, a recent study by Beeckman *et al.* (Beeckman et *al.*, 2008), could be pointed out which deals with improving the ability of students in the classification of different PU types and their differentiation from those other wounds produced as an effect of skin humidity.

Considering the main goal of minimizing the user's system requirements, PULAB's e-learning module is being currently developed using web-based technologies, which will allow using a simple web browser to have full access to the complete functionalities offered by this software tool. Moreover, for the sake of usability, AJAX technology is being used in the designing of the graphical user interface with the major objectives of building complex controls in the forms, minimizing the data communication and facilitating the interaction between the user and the system. PULAB's e-learning module is being designed as an adaptive learning interface, which will enable the students to receive their education in an manner adapted to his or her particular background-knowledge level, this way starting from initial simpler diagnosis cases and progressively going to more complex examples of PU evaluations and diagnosis. Experts and professional clinicians will be included in PULAB with the profile of "teacher" and will be able to continuously add new evaluated PU cases in the database, which can be adaptively included in the sets of PU samples available for their students. The teachers will be provided with tools for designing and managing tests for their students, in order to evaluate their educational progressions. Both, the teachers and the students, will be supplied with statistics tools to monitor the learning evolution and progressions.

Once the PULAB's e-learning module had been developed, these authors will proceed to the validation of this software as an efficient educational tool, by means of comparing the educational results obtained from the application of PULAB with those outcomes coming from the application of traditional teaching classes. The initial proposed hypothesis for this validation phase establishes that the PULAB tutoring system, as an educational software designed specifically for adaptive education on PU management, diagnosis and treatment, would increase the underlying knowledge and improve the aptitudes for diagnosis, classification, tissue differentiation and therapeutic decision-making for undergraduate Health currently students, in comparison with those results obtained with traditional teaching methods on PUs management.

## 4 CONCLUSIONS

PULAB tool has been developed to make possible the objective evaluation of pressure ulcers. This software enables teleassitance as well as the collaborative work of professional clinicians. PULAB tool consists of an internal core, hosted in the application-server, that uses computational intelligence techniques for image segmentation and tissue detection, which have demonstrated recently high efficiency rates when applied to real pressure ulcer images. Finally, the incorporation of an e-learning module into PULAB tool will make possible to have an educational tool which will

increase the efficacy of the learning process on students or professionals on pressure ulcer evaluation, diagnosis and care or pharmacological interventions. The development and validation of this e-learning module will be concluded in a few months. Finally, a remarkable issue to be considered is the possibility of using this same technology implemented in PULAB for the evaluation and diagnosis of other sort of skin wounds that require a teleassistance management similar to the one used with pressure ulcers and implemented in PULAB. That could be the case of burn wounds or even different types of melanomas.

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