
Imparting 3D representations to Artificial Intelligence for a full assessment of pressure injuries

Summary of contributions

This Ph.D dissertation studied new approaches of Deep Learning to tackle one of the important health issues in the medical sector using imaging techniques. It revolves around the assessment of pressure injuries which represent a serious health issue especially in elderly and bed-bound individuals. Using 2D and 3D imaging techniques, along with Deep Learning technology, the objectives which were set in the beginning of the thesis were successfully met.

This dissertation work has provided several contributions in medical imaging in the form of end-to-end frameworks, including preprocessing of the data, the design of Deep Learning architectures suitable for each type of data and reliable results using typical validation metrics of each application, and the integration of those methods in a web-based application. All the four main specific objectives of this dissertation were fulfilled during the research process:

- **To construct a database containing 2D photographs and 3D meshes of pressure injuries:**
This objective was successfully completed by collaborating with several hospitals in the region of Bilbao (Cruces Hospital, Santa Marina Hospital, Basurto Hospital) and doing hospital visits during a period of 24 months in order to acquire the data necessary to conduct the research, in addition to personal visits to patients houses. The database was finally composed of 210 photographs of pressure injuries, where 35 has a corresponding 3D mesh. There are no similar datasets found in the literature, containing 3D meshes of wounds.
- **To define the current state of the art achievements in pressure injury imaging systems.**
This objective was successfully completed by the publication of a review article that consisted of an analysis of wound imaging techniques with artificial intelligence, offering a literary review combined with the novelty of Deep Learning techniques to tackle this medical application. A total of 109 out of 198 papers retrieved from 8 databases have been analysed, including also contributions on chronic wounds and skin lesions

- **To design and implement algorithms for the segmentation, classification and measurement of pressure injuries:** This objective which represents the core part of this study case was fulfilled by designing two end-to-end systems. The first proposed system is based on a Convolutional Neural Network (CNN) devoted to performing optimized segmentation of the different tissue types present in pressure injuries (granulation, slough, and necrotic tissues). The obtained results showed an overall average classification accuracy of 92.01%, an average total weighted Dice Similarity Coefficient of 91.38%, and an average precision per class of 97.31% for granulation tissue, 96.59% for necrotic tissue, and 77.90% for slough tissue. The second proposed system automatically segments and measures all the quantitative characteristics of pressure injuries using their 2D and 3D information. Then, the developed algorithms for segmentation were integrated in a web-based application in order to enable the doctors to track the healing of the wound by following the evolution of the tissue types inside the wound, its measurements and infection.
- **To integrate the algorithms within a web-based application connected to a sensor device:** The developed algorithms for image segmentation and tissue classification were integrated in a web-based application, which contains the data acquired from a sensor device designed for a non-intrusive assessment of pressure injuries and infection detection. By the means of this application, the doctors can easily track the evolution and healing of the wound through the time using different visualisation graphs. This is currently being validated for a future use in hospitals in the area of Bilbao, Spain.

From the obtained results, we can state that use of Deep Learning can definitely take medical decisions to the next level, improving the quality of diagnosis of several health issues by providing reliable results to care givers from the analysis of patients' data. The motivation for conducting this research in some of the crucial medical issues that we are facing in our society nowadays arises from the eagerness to take medical research to a higher level in order to alleviate the severity of such health issues because of a lack of prevention or assessment tools. Meeting with physicians and caregiver has not only helped us to better conduct this research, but also confirmed to us the necessity of such novel methods to deal with these health issues.