# Semi-invertible Convolutional Neural Network for Overall Survival Prediction in Head and Neck Cancer

Saif Eddine Khelifa
USTHB, Algeria

Lyes Khelladi
CERIST Research Center
Algiers, Algeria

Miloud Bagaa
Aalto University
CSC, Espoo, Finland

Yassine Hadjadj-Aoul
Univ. Rennes, Inria, IRISA,
France

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***Abstract*—The paper addresses the issue of overall survival prediction in head and neck cancer as an effective mean of improving clinical diagnosis and treatment planning. A new solution is proposed using semi-invertible convolutional networks. Our model exploits the 3D features of computed tomography (CT) scans to enrich the dataset used in the learning phase and thereby improve the prediction accuracy. This is achieved by designing a first architecture featuring a combination of a CNN classifier with a fully convolutional network pre-processor. The latter has been replaced in the second solution by an invertible network to deal with the memory constraints noticed in the first architecture. Obtained results showed that both architectures have led to considerable improvements in terms of prediction accuracy ($0.75$) compared to state-of-the-art solutions.**

## I. Introduction

Head and Neck Cancers (HNC) are among the most common cancers. The HNC patients are characterized by a poor prognosis [1]. Of note, the survival rates of incurable HNC are concise. The overall survival rates of HNC cancer vary significantly according to the location and stage of the tumor. These make this type of cancer a source of utmost concern to the patients and physicians. Therefore, early diagnosis and prognosis are essential for the proper management of HNC patients [2]. Several attempts have been made for patients' prognosis estimation. For instance, the experience of the oncologists is well-positioned to estimate the prognosis of the patients [2]. However, oncologists are concerned about the possibility of making inaccurate prognoses. Additionally, this approach can be subjective and increases the risk of bias [2], [3]. The traditional statistical analysis method was outperformed by disruptive technology such as the sub-field of artificial intelligence, that is, deep machine learning in the prognosis of cancer outcomes [4], [5].

The deep learning technique leverages the improved computational power to modify the widely known artificial neural network architecture. It is a specialized machine learning technique that uses a multi-layered neural network [6]. This multi-layered architecture is able to learn the potentially complex and hidden relationships between various variables contained in the input data. Consequently, the learned relationships between these variables are used to define the output of interest, such as the overall survival of HNC patients. The deep learning technique has been reported to have significant importance in the proper management of head and neck cancer [7]. The study by Howard et al. [7] has reported the potential of deep learning techniques to identify the patients that could benefit from chemo-radiation.

The study, accomplished by Diamant et al. [8], has explored the potential of deep learning techniques to enhance the performance of traditional radiomics [8]. The latter has used computed tomography (CT) scans as the primary modality rather than other modalities, such as magnetic resonance and positron tomography. Formally, these scans are fundamental, and each modality provides different information on the tumor. CT scans are obtained from an X-ray study that produces 3D cross-sectional images of the body. Therefore, this modality can be used to reveal the tumor volume and the blood vessels that are feeding the tumor, and hence it provides more details on the tumor.

In this work, we examine the use of deep learning models applied to pre-treatment CT scans to predict overall survival in head and neck cancer. The proposed approach aims at improving the predictive accuracy for the proper management of this cancer through effective treatment and informed clinical decisions. Furthermore, we explore the potential of having 3D inputs (CT scans volume) instead of having 2D inputs (CT scans slice) to enrich the features extraction using a deep learning network by adding the spatial information between slices in the Z space. We devised two solutions for head and neck cancer survival prediction. While the first solution relies on a fully convolutional network, the second one uses the semi-invertible fully convolutional network to reduce memory utilization. The obtained results demonstrate the efficiency of each solution for achieving its design goals.

The remainder of this paper is organized as follows. First, section II briefly describes the most recent related works in the scope of predicting overall survival for HNC patients. Section III describes the employed dataset and the methods used for data filtering and pre-processing. Section IV presents the limitations of architectures based on datasets of 3D CT scans and the solutions to tackle those limitations. In section V, we present the proposed deep learning model for overall survival prediction. Section VI provides a comparative discussion considering results obtained in previous studies. Additionally, it emphasizes the clinical implications of the