Deep learning methods for 2D in-vivo dose reconstruction with EPID detector

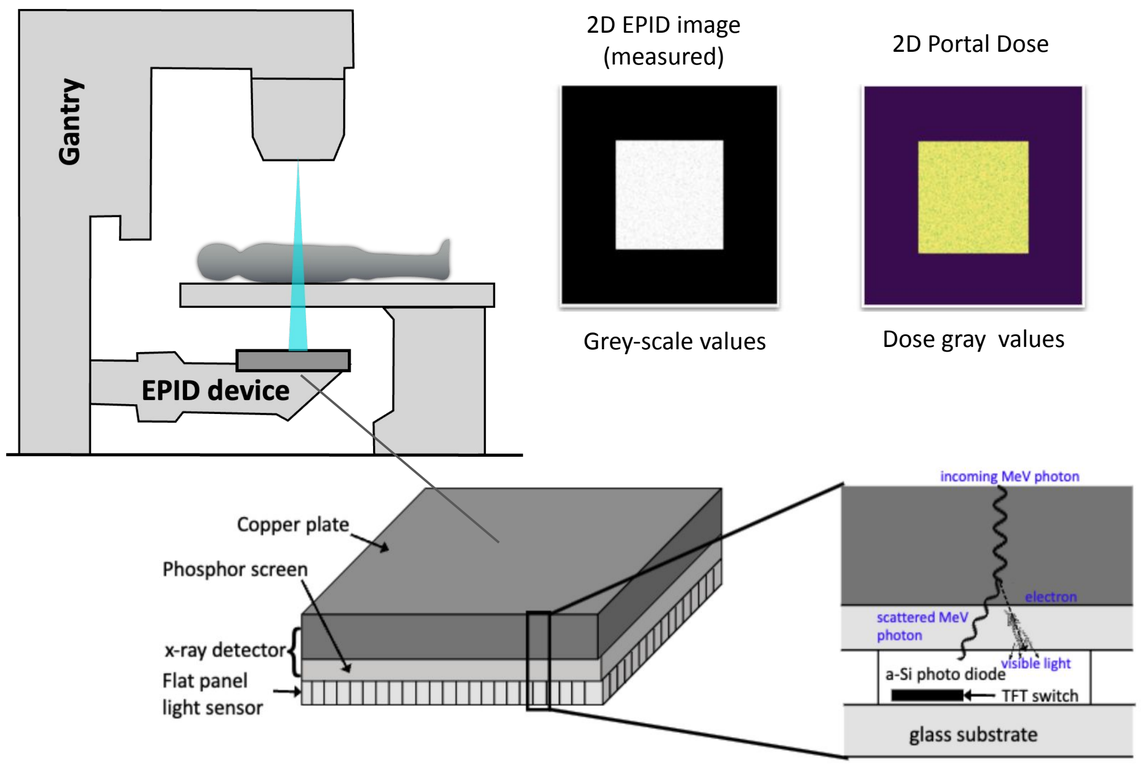
L. Marini[1, 2], M. Avanzo[3], A. C. Kraan[2], F. Lizzi[2], C. Mozzi[4], A. Retico[2], C. Talamonti[4, 5]

(1) Università di Pisa
(2) INFN Pisa
(3) Centro di Riferimento Oncologico (CRO) di Aviano
(4) Università di Firenze
(5) INFN Firenze

State-of-the-art

Introduction

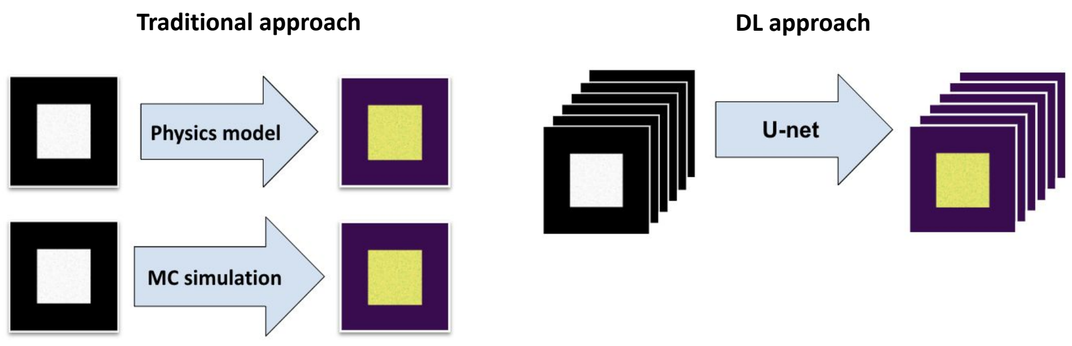
In the past few years, **Electronic Portal Imaging Devices** (**EPID**) have gained prominence for pre-treatment dose verification and real-time monitoring in radiotherapy (RT). These detectors function by recording the X-ray fluence on a pixel-based surface to produce a 2D digital image. Their rapid image capturing ability, high resolution, good linear dose response, and long-term stability make them advantageous.



Utilizing EPIDs necessitates the modeling of their response to estimate the 2D dose distribution (**Portal Dose**, **PD**). This modeling is crucial to compare the predicted and measured PD and to verify whether an error occurred during treatment.

Traditional vs modern approach

Traditionally, the EPID response modeling is based on **physical models** and **Monte Carlo techniques**. However, these methods are complex and time-consuming, involving linac geometry, EPID structure details, and several preprocessing steps like sensitivity matrix adjustment, dose response calibration, and EPID scatter correction, making them impractical for widespread clinical use.



Artificial Intelligence, specifically **Deep Learning** (**DL**), has great potential to enhance the efficiency and precision of **in-vivo dosimetry** in RT. A DL-system can analyze examples and learn to model the EPID response, enabling accurate estimation of 2D dose distributions without reliance on traditional physical models.

Research objective

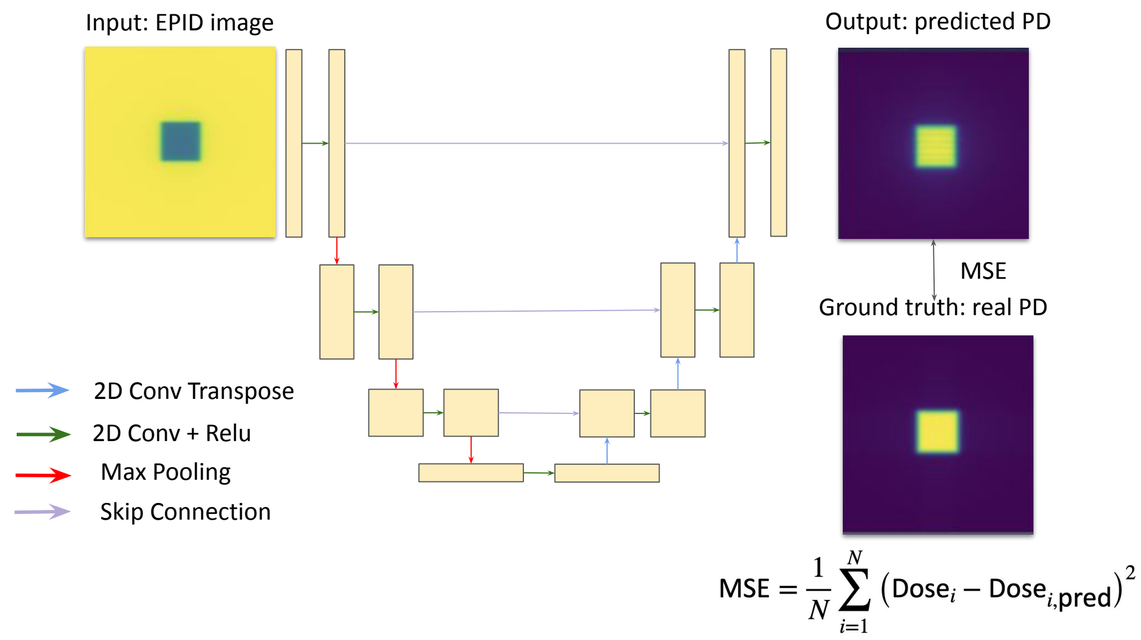
This project aims at developing a DL-based methodology, employing a trained U-net architecture, to convert the actual EPID responses (captured as grey-scale images) into PD images (in dose Gray values) calculated by a Treatment Planning System (TPS).

Materials & Methods

Data collection

Our database is composed of one hundred 2D portal dose images generated by Elekta's **TPS Monaco**, plus an equal number of EPID images, that were acquired for various phantoms representing different material densities (lung, solid water, titanium, and bone).

Deep Learning model, training phase and predictions

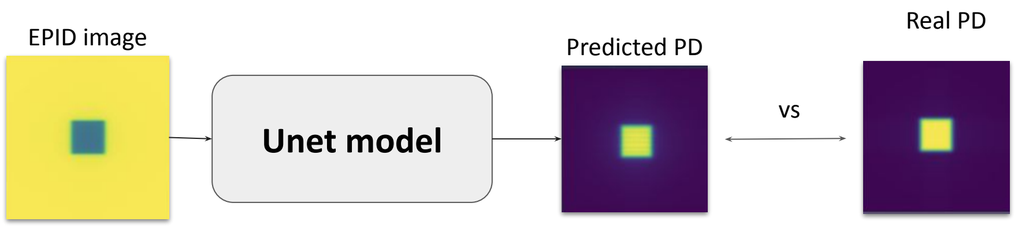


$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}\left(\mathrm{Dose}_i - \mathrm{Dose}_{i,\mathrm{pred}}\right)^2$$

We developed a **U-net architecture** aiming at mapping EPID images into PD and tracked the **Mean Absolute Error** (**MAE**) as a metric to quantify the difference between the model predictions and targets. The loss function used in the training model was the **Mean Square Error** (**MSE**).

Evaluation of the performance

The quality of predicted dose distributions was assessed through the **gamma-index analysis** of 3%/3 mm and 5%/5 mm.



$$\Gamma(\mathbf{r}_{\mathrm{real}}, \mathbf{r}_{\mathrm{pred}}) = \sqrt{\frac{\Delta\mathbf{r}^2(\mathbf{r}_{\mathrm{real}}, \mathbf{r}_{\mathrm{pred}})}{\delta r^2} + \frac{\Delta D^2(\mathbf{r}_{\mathrm{real}}, \mathbf{r}_{\mathrm{pred}})}{\delta D^2}}$$

Results and Conclusions

A **standard gamma analysis of 3%/3 mm and 5%/5 mm** was performed on the PD predicted by the DL network and the simulated PD in the test dataset, demonstrating promising gamma pass rates. In this study, we converted the measured EPID response into the actual PD using a DL network and compared it with the simulated PD calculated by TPS. Our preliminary results underscore the significant potential of DL methods in accurately predicting the dose delivered to EPID detectors during radiotherapy treatments.

Acknowledgments

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lorenzo.marini@pi.infn.it