Doctoral School of Information and Biomedical Technologies
Polish Academy of Sciences (TIB PAN)

SUBJECT: AI-Driven Solutions for Early Pancreatic Cancer Diagnosis and Therapy

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Name of the institute in which the topic will be realized: **Institute of Fundamental Technological Research**
Scientific discipline: **Information and communication technology**

PROJECT DESCRIPTION

Early cancer diagnosis and treatment significantly improve survival rates, emphasizing the need for advanced diagnostic tools. Imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) are critical for tumor visualization [1]. Enhanced 3D visualization of segmented organs and vessels is pivotal for surgical planning, reducing intraoperative uncertainties, and improving outcomes. Manual segmentation, still widely used, requires experts to annotate scans, making it time-consuming, resource-intensive, and prone to variability based on operator skill. Challenges stem from the complex anatomy, variable organ positions, and subtle boundaries [2]. Small organ sizes and faint contrasts between structures further complicate accurate segmentation, highlighting the need for precise automated solutions. Artificial Intelligence (AI), particularly Deep Learning (DL), has revolutionized medical imaging, with AI-based algorithms excelling in early-stage cancer detection and disease assessment. Deep neural networks (DNNs), particularly Convolutional Neural Networks (CNNs) like U-Net, U-Net++, R2U-Net, and NAVT-Net have shown exceptional performance in image segmentation [3-6]. Despite these advancements, challenges persist in processing medical images, especially when dealing with low-quality scans. Current methods often rely on human oversight, which limits scalability and efficiency. This underscores the urgent need to develop automated, robust, and accurate segmentation algorithms that can adapt to diverse imaging conditions and complex anatomical features.

Research Objectives and Approach

This doctoral thesis aims to develop and implement innovative AI-driven segmentation algorithms to improve diagnostic and therapeutic workflows for cancer. By leveraging state-of-the-art Machine Learning (ML) techniques, the research will focus on the following objectives:

- **Automated and Accurate Segmentation:** development and implementation of the algorithms capable of precise automatic segmentation of organs and abnormalities in CT and MRI scans. These algorithms will enhance the delineation of boundaries even in cases of subtle contrasts between the organ and background.
- **Lesion Classification and Visualization**: Integration of classification capabilities to distinguish between different lesion types and generate detailed 3D visualizations of affected regions.
- **Optimization of Traditional and Deep Learning Models:** Address key challenges in feature extraction for classical ML approaches and hyperparameter tuning in DL networks. For instance, classical models require robust data-driven feature extraction mechanisms, while DL models necessitate optimization of parameters such as layer architecture, regularization techniques, and dropout settings, often determined heuristically.

Datasets

The training and testing datasets for these algorithms will consist of MRI and CT scans, combined with 3D images from patients. These datasets will be constructed using publicly available retrospective sources and additional data obtained from research partners. By addressing the challenges of manual segmentation and leveraging state-of-the-art AI technologies, this research aims to contribute significantly to the advancement of medical imaging and the early detection of cancer.

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