<KIV> KATEDRA INFORMATIKY A VÝPOČETNÍ TECHNIKY

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Possibilities of Using Multimodal Vector Data Representations in Personalised Medicine

Diploma thesis

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Abstract

The thesis deals with multimodal vector representations of data and their use in personalized medicine. In the first, theoretical, part, the principles of multimodal vector representations are presented and methods for their creation are described. In the practical part of the thesis, a model for predicting the functional outcome (mRS) of patients after stroke (CMP) is designed and trained, which integrates the tabular modality (structured clinical data) and the image modality (3D CT perfusion scans of the brain). The output of the thesis is an application that allows predicting the patient's mRS and searching for the closest historical cases.

Introduction

The aim of the thesis is to explore the principles of multimodal vector data representations and demonstrate their use in personalized medicine. In the practical part of the thesis, an application was designed for predicting the functional outcome of patients after stroke (CMP) using a suitably selected multimodal dataset obtained from the MRE (Medical Research and Education) platform.

Starting points, analytical part

In the field of multimodal machine learning, two basic approaches are distinguished for creating a multimodal representation:

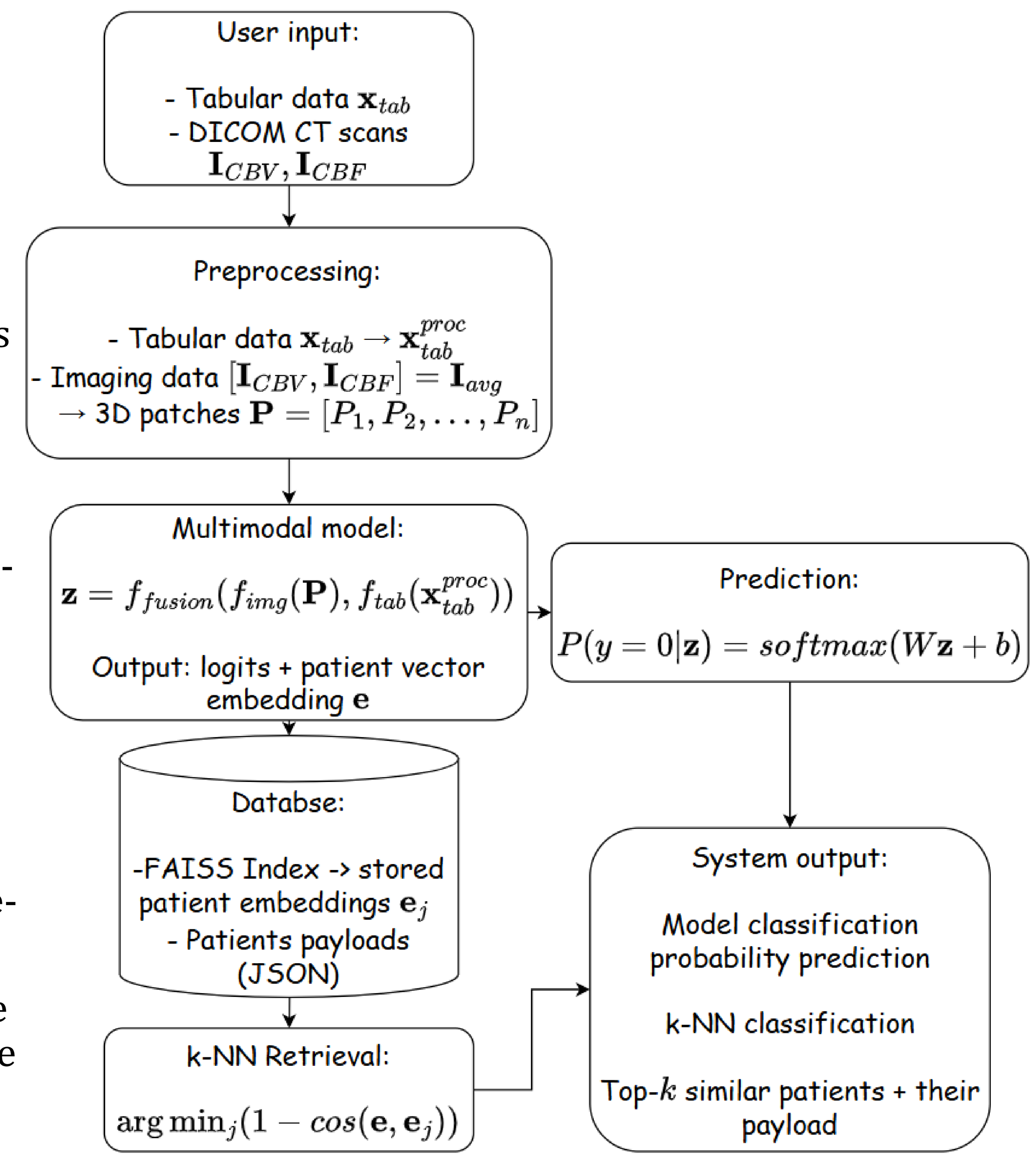
- Joint representation - a unified vector space is created in which individual modalities are directly integrated (using multimodal fusion).
- Coordinated representation - here each modality has its own vector space, but these spaces are aligned together so that cross-similarity across modalities can be measured.

The paper describes in more depth the principles and properties of both approaches, including related areas (fusion, alignment of modalities, contrastive learning). It also introduces the concept of personalized medicine and lists the areas where multimodal models are most frequently used.

Main aspects of implementation

In the practical part, a suitable dataset of 808 patients meeting all the criteria was selected from the SPARQL database of the MRE platform. The mRS prediction model combines 3D CT perfusion scans and clinical data into a common 128-dimensional vector. The image branch uses a patch-based convolutional encoder with residual blocks, positional coding and attention pooling. The clinical branch consists of a simple MLP with two hidden layers, with both representations being connected using a lightweight but efficient GMU fusion. The model has two output heads – a classification head for dichotomized mRS and a projection head for creating vector embeddings, which allows simultaneously optimizing the prediction accuracy and the quality of the vector space.
A combined loss function consisting of classical cross-entropy and supervised contrastive loss was used when training the network.
After training the model, a vector index (within the FAISS framework) was built for efficient vector search.

The entire application is then built as an interactive web dashboard that connects input processing, model inference, vector index for k-NN classification, and searching for similar historical cases.



Schema of Stroke Outcome Predictor Application

Achieved results

The model achieved a ROC AUC = 0.83 on the balanced test dataset, which means an 83% probability of correctly distinguishing between good and poor functional outcome (mRS), F1 score achieved 0.82. K-NN classification over the vector index of historical patients showed an accuracy (k-NN accuracy) of 81%, confirming the discriminative ability of the created vector space.

Conclusion

The aim of the thesis was to introduce multimodal vector data representations and personalized medicine, which was achieved in an extensive theoretical part. Another aim was to create an experimental prototype of an application using appropriately selected multimodal data for the purpose of predicting functional outcome, which was achieved by the Stroke Outcome Predictor application.

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