

Figure 1.The framework of our proposed method xxx consist of four main components : (a) The raw ultrasound video is initially departed into several clips. (b) The Multi-exports Mask Generation Network conduct the calculation of the token score (c) The encoder is trained by reconstructing the masked the cubic tokens according to the token score with decoder. (d) The final diagnostic result of a prostate ultrasound imaging clip is calculated using the token score and features extracted by the encoder through the classification head.

(这里的字体给改成了times new roman,字号为5号，两端对齐，你看着同步修改一下)

**3.Methodology**

In this section,we first present the motivation and overall framework of the proposed method Medical-MAE in Section 3.1. Next , we turn into the details of the proposed Multi-exports Mask Generation Network (MeMGN) in the pre-training phase and the additional prompt based on MMGN in the downstream classification fine-tuning phase in Section 3.2 and 3.3.

**3.1 Overview**

**3.1.1 Motivation**

Given a prostate ultrasound video contains frames , we aim to address the following two issues:

1. ***Insufficient key region representation pre-training leads to details missing****：*The mainstream masking methods lack the concentration on the lesion areas of prostate ultrasound images, which may influence the feature extraction in these key regions crucial for downstream tasks.
2. ***Direct applying general masked features leads to insufficient classification***: Most downstream classification methods using masked features directly on the pre-training encoder, which may cause the model to overlook generalizable features, weakening robustness and cross-domain performance.

To address these issues , we propose xxx that mask the tokens by MeMGN, guided by multiple pre-trained medical expert models and give additional prompt based on MeMGN in the downstream classification fine-tuning. This enables us to make the training of our encoder **representation extraction focus on key regions** , while paying more attention to **general features** during classification fine-tuning.

**3.1.2 Framework**

In this section , we will briefly introduce the overall framework of the proposed xxx in Fig.1. Given a prostate ultrasound video , which contains represents the frame, height, and width of the video. The objective of XXX is to focus on key regions in prostate ultrasound images to achieve highly accurate classification. The framework is divided into two stages: pretraining and fine-tuning. Here's a refined and academically appropriate version of your paragraph, with improved clarity and structure:

The objective of the pre-training phase in our XXX framework is to train the encoder to learn meaningful feature representations from video ultrasound images. The input video is divided into non-overlapping 3D cubic tokens of size . Then, the token is projected into a feature vector of dimension (set to 768 in our design). During the fine-tuning phase, the encoder extracts features from the input video are fed into a classification head to predict the final label of the video.

**3.2 Multi-exports guided Pre-training**

This section first provides a brief overview of the main framework in the pre-training phase, then delves into our proposed multi-expert mask generation network.

**3.2.1 Pre-training phase**

For an input video *V* with *T* frames, we adopt a data sampling strategy with a stride of 4 to reduce redundancy, resulting insampled frames. These frames are further divided into *L* clips *C*, each containing consecutive frames (equals to 16 in our setting), where. Consequently, the input to the pre-training network is represented as *C* .

First, the input clip *C* is embedded by a 3D convolution to reduce its dimensionality to , where *N* represents the token number which is equal to . The operation can be formulated as:

(1)

where represents the 3D convolution operation, then the token and the clip are given to the MeMGN , outputing the mask scores , which can be represented as:

(2)

Next, to highlight the importance of key regions, we apply masking to the top‑K tokens with the highest scores, where , and denotes the masking ratio. The remaining unmasked tokens are fed into the encoder of Vision Transformer for feature extraction and representation. This process can be formulated as follows:

(3)

Finally, the encoded visible tokens is concatenated with masked tokens to get the combined tokens , which is then fed into the decoder of the Vision Transformer to obtain the reconstruction result .

(4)

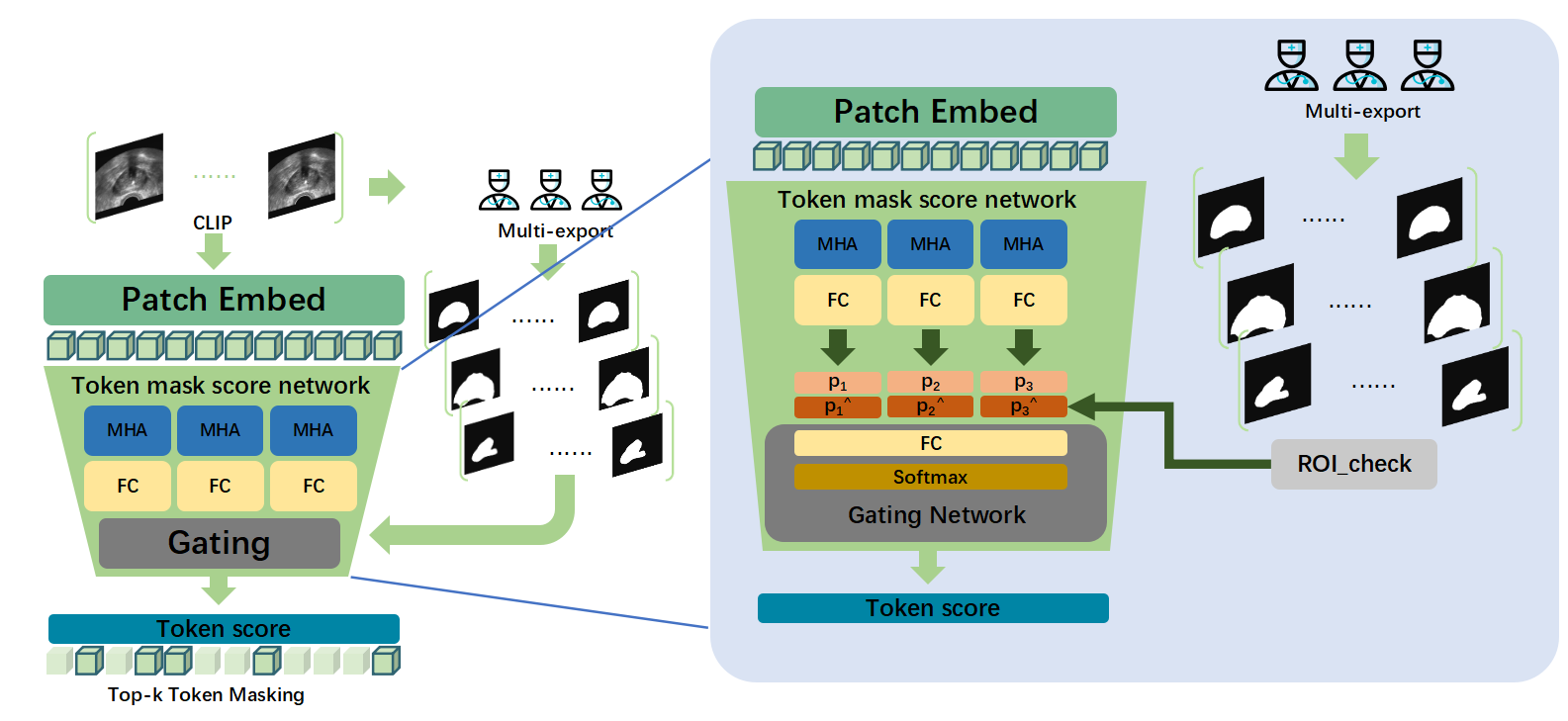


Figure 2.Detailed structure of the proposed MeMGN , including four steps : (a) The input cubic tokens perform Multi-head attention (MHA) operations at different tokens to obtain the basic token scores.(b) Raw images of input clip get segments from pretrained export models.(c) Some of the basic token scores are increased due to the segments provided by export models.(d) Three different exports’ token scores are fused by Gating Network to obtain the final output token scores.(这里我没有修改，你得先改图，图中的a,b,c,d标注了再对照着写相关的caption描述)

（改图2）

**3.2.2 Multi-exports Mask Generation Network**

As illustrated in Fig. 2, we introduce a Multi-Expert Mask Generation Network (MeMGN), which comprises three distinct token mask scoring sub-networks and their corresponding expert models. This design effectively captures the importance of lesion regions and their relationships with surrounding areas. The following section outlines the main workflow of MeMGN.

First, given the input token , MeMGN creates three identical copies of the input token, each of which is used by one of the three expert models.、

(5)

where represents the copy operation and is the embedded token for the i-th expert.

Then, multi-head attention is applied to each input token to extract contextual information and automatically determine the importance of each token, guiding the network to learn representations of critical regions. This process can be formulated as follows:

(6)

where represents a series of multi-head attention blocks.

Next, is fed into the fully connected layer to get the initial token score:

(7)

Subsequently, to emphasize important regions related to segmentation, the binarized mask from the i-th expert segmentation is also patchified into parts, which can be expressed by the following formula:

(8)

where , denotes the j-th embedded cubic token of and , the represents extracting the tensor element located at . Then, we flatten all the values to obtain the final a priori knowledge proposal  *.*

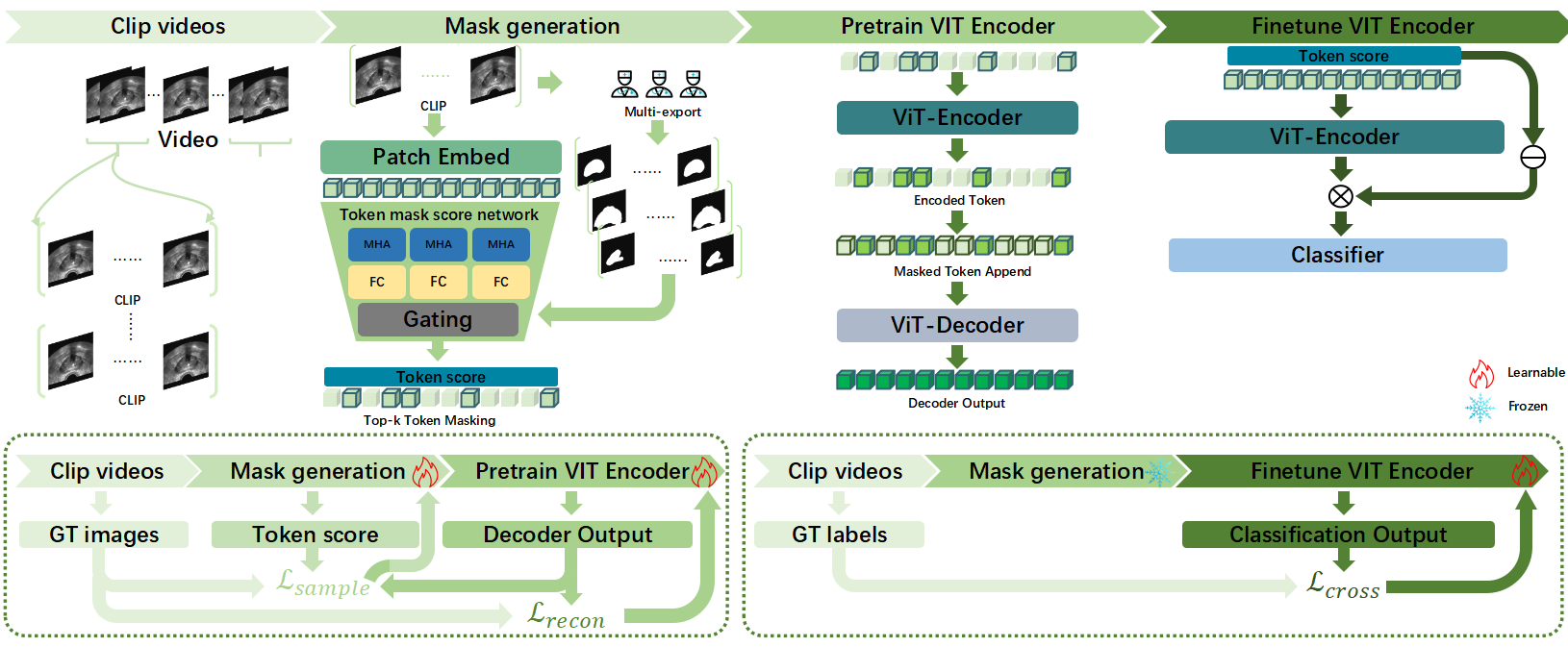
Then, for the key regions, we add an increment to the original probability if the patch is in the priori knowledge proposal area to correct the probability values learned by the network:

(9)

Finally, we employ a learnable gating mechanism that integrates the corrected probabilities from multiple experts through a fully connected layer and applies a softmax remapping to obtain the final importance score :

(10)

(11)



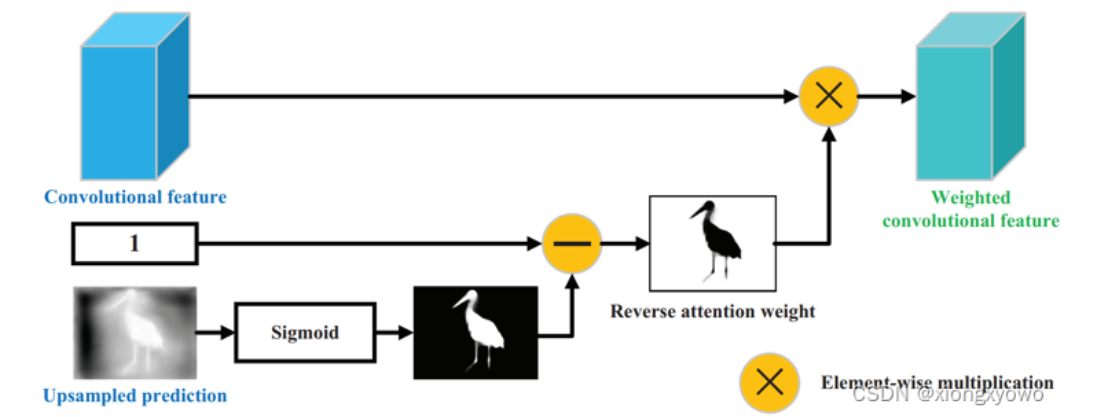


Figure 3.Fine-tuning phase

**3.3 Multi-exports guided fine-tuning**

In the fine-tuning phase, we use only the encoder and MeMGN network from the pretraining phase, and then adjust the classification head specifically for the classification task in this work.

**3.3.1 Fine-tuning phase（这里没有图我不太好改，给你个参考写法）**

**（已经有的不用重复写，直接说参照前面预训练阶段的设定，我们获得了哪些东西，如你下面提到的特征和分数，重点体现和上一个阶段不一样的地方，也就是后面微调的部分，怎么对这些特征进行分类头的改进！ 我下面用橙色字体标注的地方可以缩短成一道两句话，然后多专家注意力的地方参考我上面预训练的地方的修改进行修改，motivated by这样的话可以写，但别展开，直接写操作和过程就行）**

Given a video *V* with label *y*. We sample the video as pre-training phase and get *L* clips *C.* The input of fine-tuning phase is also represented as *C ,* where denote the length of a clip, the height and the width of frames.

The clip *C* first is embedded to obtain the cubic token as the pretraining phase. Then, the token along with the Segments *S* are jointly input to the pre-trained MeMGN to generate the mask scores .

Afterwards the embedded tokens are transmitted to the pretrained encoder to obtain the basic feature , which can be described as follows:

(12)

Where represent the pretrained encoder blocks. With the guidance of the mask scores , the final feature of outcome comes from the proposed Multi-exports guided attention (MeGA) operation:

(13)

Where represents the Multi-exports guided attention operation. Finally the output of the final feature is used to make the classification result with a classification head composed of a fully connected layer and a softmax operation, which is formulated as:

(14)

where and represent fully connected layer and softmax operation.

**3.3.2 Multi-exports guided attention**

The Vision Transformer based network can provide reliable features, but fine-tuning for classification tasks, especially when the dataset is smaller (compared to the pre-training phase), tends to lead to overfitting. Feature extracted by the vision transformer encoder become more global as the depth increases , while the shallow features generalizable features and can better represent the textural and structural patterns of the image. Leveraging this property, inspired by[6], we perform a reverse attention map multiplication operation using the mask scores generated by MeMGN to enhance generalizable features.

As shown in Fig.3, the input mask scores generated by pretrained MeMGN is are first sign-flipped and then passed through the sigmoid function , yielding a normalized mask probability . Subsequently, the computed mask probability and the basic feature extracted by pretrained encoder perform an element-wise multiplication, which can be summarized as:

(16)

(17)

where denotes the feature of all the cubic tokens. In the end , the final feature is generated by averaging across all token dimensions to create a global feature guidance, representing the overall information of the input image, rather than using a single CLS token like vision transformer.

**4.Datasets**

The training data used in this study are mainly collected from Shanghai Tenth People’s Hospital affiliated with Tongji University, consisting of 652 ultrasound video cases with a total of 89,355 frames. Among them, 338 cases are suspected of having lesions and 314 cases are identified as T1 stage, resulting in a relatively balanced distribution. To evaluate the generalization ability of the proposed model, an external validation set is constructed using 182 non-invasive prostate ultrasound videos collected from three additional medical centers: Bengbu People's Hospital, Ningbo No. 2 Hospital, and Fudan Zhongshan Hospital. The dataset is of large scale and high quality, covering multiple hospitals and a variety of ultrasound equipment, thereby providing a robust foundation for model training and evaluation.

To remove patient privacy information and other irrelevant elements such as watermarks, we employ the open-source tool LabelImg to annotate and crop the regions of interest. Furthermore, to meet the resolution requirements of the input data, all frames from the same video case are uniformly resized. Specifically, the longer side of each frame is scaled to 512 pixels, while the shorter side is padded with black borders to achieve a final resolution of 512×512 pixels. As a result, we obtain a total of 89,355 frames for training and internal validation, and 42,691 frames for multi-center external validation.

As described in Section 3.2 and 3.3 , We applied three pretrained medical segmentation models as our multi-experts guidance to guide the generation of mask in the pretraining phase and the feature extraction in the fine-tuning phase. We first utilize the Medical Segment Anything 2[2] to generate segment for the guidance. However, using ChatGPT[3] to generate the role prompt for MedSAM2. The overall generation process of the segment for the first export can bu summarized as follows:

(9)

Where represents the Medical Segment Anything 2 model. and are the raw image of ultrasound video and role prompt given by ChatGPT. For the other two expert models, we chose medical segmentation models nnUNet[4] and deeplab-v3[5] with pretrained weights which comes from ultrasound imaging of regions such as the gallbladder, breast, and others. The process by which these two pretrained experts provide segmentation guidance can be described as:

(10)

(11)

Where and represent the nnUNet2 model and Deeplabv3 model.

Finally, we saved the segments *S* that given by our chosen pretrained expert models as images for pre-training and fine-tuning phases.

**5.Experiments and analysis**

**5.1 Experimental Setups**

3.4.1 Multi-exports Mask Generation Network

To jointly constrain the MeMGN network and the visual representation model, we design sampling loss, smoothness loss, and reconstruction loss.

**Masking Reconstruction Loss.** We adopt the Mean Squared Error (MSE) loss to constrain the reconstructed values and the ground truth, which is formulated as follows:

, (4)

where and denote the predicted token and the ground-truth values of the token.represent the number of masked tokens.

**Smoothness Loss.** To mitigate block artifacts caused by overfitting or discontinuities in the image, we introduce a smoothness loss. Specifically, we apply smoothness constraints in both the vertical and horizontal directions to reduce abrupt changes between neighboring pixels, encouraging the generation of more natural and coherent images. The loss is formulated as follows:

(5)

(6)

**Token Sampling Loss.** To maximize sampling accuracy, inspired by AdaMAE, we designed a sampling loss. This loss applies stronger constraints on high-information regions prone to errors while relaxing constraints in low-information areas, encouraging the network to assign higher probability scores to high-information regions. The loss function is defined as follows:

, (8)

where denote the probability of the token to be masked. In the pre-training

**Reference**

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