Table 1. Enumeration of the abbreviations used in the paper.

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Description | Symbol | Description |
| H&E | Hematoxylin and eosin staining | WSIs | Whole slide images |
| SPC | Spermatocyte cell | RS | Round spermatid cell |
| SPG | Spermatogonia cell | SC | Sertoli cell |
| CSS | Computerized spermatogenesis staging | CSNet | Channel and spatial attention network |
| MTL-CSNet | Multi-task learning with CS-Net | MSL | Multi-scale learning |
| *#* | Number | BEOHD | Bag Of Edge Histogram and Distance |
| MTCs | Multiple testicular cells | MCLs | Multi-concentric layers |
| PLSeg | Prostate lumen segmentation | MoNuseg | Multi-organ Nucleus Segmentation |
| EPSTSeg | Epithelium & stroma segmentation | KIRCseg | kidney renal clear cell segmentation |
| mSen | Mean Sensitivity | mIoU | Mean Intersection over Union |
| CSNet-MTCs | The baseline model of CSNet for MTCs segmentation on Stages I-V | MTL-CSNet-MTCs | MTL-CSNet for MTCs segmentation on Stages I-V |
| MTL-CSNet-MTCs-SAAT | MTL-CSNet-MTCs with Spermatogenesis-Agnostic Auxiliary Tasks | MTL-CSNet-MTCs-SSAT | MTL-CSNet-MTCs with Spermatogenesis-Specific Auxiliary Tasks |
| MTL-CSNet-MTCs-SAAT-PLSeg | MTL-CSNet-MTCs-SAAT with PLSeg datasets | MTL-CSNet-MTCs-SAAT-MoNuseg | MTL-CSNet-MTCs-SAAT with MoNuseg datasets |
| MTL-CSNet-MTCs-SAAT-EPSTSeg | MTL-CSNet-MTCs-SAAT with EPSTSeg datasets | MTL-CSNet-MTCs-SAAT-KIRCseg | MTL-CSNet-MTCs-SAAT with KIRCseg datasets |
| MTL-CSNet-MTCs-SSAT-MTCsSeg | MTL-CSNet-MTCs-SSAT with MTCsSeg datasets on Stages VI-VIII | MTL-CSNet-MTCs-SSAT-MCLsSeg | MTL-CSNet-MTCs-SSAT with MCLsSeg datasets on Stages VI-VIII |
| TP | True Positive: The Positive sample is successfully predicted to be Positive | TN | True Negative: The Negative sample is successfully predicted as Negative |
| FP | False Positive:Incorrectly predict a Positive from a negative sample | FN | False Negative:Positive samples are incorrectly predicted as Negative |

Table 2. The nuclei-level features of 140 descriptors.

|  |  |  |
| --- | --- | --- |
| area | shape | staining |
| 1.area\_mean of RS | 1.major\_mean of RS | 1.rMean\_mean of RS |
| 2.area\_std of RS | 2.major\_std of RS | 2.rMean\_std of RS |
| 3.area\_skewness of RS | 3.major\_skewness of RS | 3.rMean\_skewness of RS |
| 4.area\_kurtosis of RS | 4.major\_kurtosis of RS | 4.rMean\_kurtosis of RS |
| 5.area\_entropy of RS | 5.major\_entropy of RS | 5.rMean\_entropy of RS |
| 6.area\_mean of SPC | 6.minor\_mean of RS | 6.gMean\_mean of RS |
| 7.area\_std of SPC | 7.minor\_std of RS | 7.gMean\_std of RS |
| 8.area\_skewness of SPC | 8.minor\_skewness of RS | 8.gMean\_skewness of RS |
| 9.area\_kurtosis of SPC | 9.minor\_kurtosis of RS | 9.gMean\_kurtosis of RS |
| 10.area\_entropy of SPC | 10.minor\_entropy of RS | 10.gMean\_entropy of RS |
| 11.area\_mean of SPG | 11.ratio\_mean of RS | 11.bMean\_mean of RS |
| 12.area\_std of SPG | 12.ratio\_std of RS | 12.bMean\_std of RS |
| 13.area\_skewness of SPG | 13.ratio\_skewness of RS | 13.bMean\_skewness of RS |
| 14.area\_kurtosis of SPG | 14.ratio\_kurtosis of RS | 14.bMean\_kurtosis of RS |
| 15.area\_entropy of SPG | 15.ratio\_entropy of RS | 15.bMean\_entropy of RS |
| 16.area\_mean of SC | 16.major\_mean of SPC | 16.rMean\_mean of SPC |
| 17.area\_std of SC | 17.major\_std of SPC | 17.rMean\_std of SPC |
| 18.area\_skewness of SC | 18.major\_skewness of SPC | 18.rMean\_skewness of SPC |
| 19.area\_kurtosis of SC | 19.major\_kurtosis of SPC | 19.rMean\_kurtosis of SPC |
| 20.area\_entropy of SC | 20.major\_entropy of SPC | 20.rMean\_entropy of SPC |
|  | 21.minor\_mean of SPC | 21.gMean\_mean of SPC |
|  | 22.minor\_std of SPC | 22.gMean\_std of SPC |
|  | 23.minor\_skewness of SPC | 23.gMean\_skewness of SPC |
|  | 24.minor\_kurtosis of SPC | 24.gMean\_kurtosis of SPC |
|  | 25.minor\_entropy of SPC | 25.gMean\_entropy of SPC |
|  | 26.ratio\_mean of SPC | 26.bMean\_mean of SPC |
|  | 27.ratio\_std of SPC | 27.bMean\_std of SPC |
|  | 28.ratio\_skewness of SPC | 28.bMean\_skewness of SPC |
|  | 29.ratio\_kurtosis of SPC | 29.bMean\_kurtosis of SPC |
|  | 30.ratio\_entropy of SPC | 30.bMean\_entropy of SPC |
|  | 31.major\_mean of SPG | 31.rMean\_mean of SPG |
|  | 32.major\_std of SPG | 32.rMean\_std of SPG |
|  | 33.major\_skewness of SPG | 33.rMean\_skewness of SPG |
|  | 34.major\_kurtosis of SPG | 34.rMean\_kurtosis of SPG |
|  | 35.major\_entropy of SPG | 35.rMean\_entropy of SPG |
|  | 36.minor\_mean of SPG | 36.gMean\_mean of SPG |
|  | 37.minor\_std of SPG | 37.gMean\_std of SPG |
|  | 38.minor\_skewness of SPG | 38.gMean\_skewness of SPG |
|  | 39.minor\_kurtosis of SPG | 39.gMean\_kurtosis of SPG |
|  | 40.minor\_entropy of SPG | 40.gMean\_entropy of SPG |
|  | 41.ratio\_mean of SSPG | 41.bMean\_mean of SPG |
|  | 42.ratio\_std of SPG | 42.bMean\_std of SPG |
|  | 43.ratio\_skewness of SPG | 43.bMean\_skewness of SPG |
|  | 44.ratio\_kurtosis of SPG | 44.bMean\_kurtosis of SPG |
|  | 45.ratio\_entropy of SPG | 45.bMean\_entropy of SPG |
|  | 46.major\_mean of SC | 46.rMean\_mean of SC |
|  | 47.major\_std of SC | 47.rMean\_std of SC |
|  | 48.major\_skewness of SC | 48.rMean\_skewness of SC |
|  | 49.major\_kurtosis of SC | 49.rMean\_kurtosis of SC |
|  | 50.major\_entropy of SC | 50.rMean\_entropy of SC |
|  | 51.minor\_mean of SC | 51.gMean\_mean of SC |
|  | 52.minor\_std of SC | 52.gMean\_std of SC |
|  | 53.minor\_skewness of SC | 53.gMean\_skewness of SC |
|  | 54.minor\_kurtosis of SC | 54.gMean\_kurtosis of SC |
|  | 55.minor\_entropy of SC | 55.gMean\_entropy of SC |
|  | 56.ratio\_mean of SC | 56.bMean\_mean of SC |
|  | 57.ratio\_std of SC | 57.bMean\_std of SC |
|  | 58.ratio\_skewness of SC | 58.bMean\_skewness of SC |
|  | 59.ratio\_kurtosis of SC | 59.bMean\_kurtosis of SC |
|  | 60.ratio\_entropy of SC | 60.bMean\_entropy of SC |

Table 3. The image-level features of 64 descriptors.

|  |  |  |
| --- | --- | --- |
| number | distance | |
| 1.number\_RS | 1.distance\_mean of RS-RS | 26.distance\_mean of SPC-SPG |
| 2.number\_SPC | 2.distance\_std of RS-RS | 27.distance\_std of SPC-SPG |
| 3.number\_SPG | 3.distance\_skewness of RS-RS | 28.distance\_skewness of SPC-SPG |
| 4.number\_SC | 4.distance\_kurtosis of RS-RS | 29.distance\_kurtosis of SPC-SPG |
| 5.number of RS-RS | 5.distance\_entropy of RS-RS | 30.distance\_entropy of SPC-SPG |
| 6.number of RS-SPC | 6.distance\_mean of RS-SPC | 31.distance\_mean of SPC-SC |
| 7.number of RS-SPG | 7.distance\_std of RS-SPC | 32.distance\_std of SPC-SC |
| 8.number of RS-SC | 8.distance\_skewness of RS-SPC | 33.distance\_skewness of SPC-SC |
| 9.number of SPC-SPC | 9.distance\_kurtosis of RS-SPC | 34.distance\_kurtosis of SPC-SC |
| 10.number of SPC-SPG | 10.distance\_entropy of RS-SPC | 35.distance\_entropy of SPC-SC |
| 11.number of SPC-SC | 11.distance\_mean of RS-SPG | 36.distance\_mean of SPG-SPG |
| 12.number of SPG-SPG | 12.distance\_std of RS-SPG | 37.distance\_std of SPG-SPG |
| 13.number of SPG-SC | 13.distance\_skewness of RS-SPG | 38.distance\_skewness of SPG-SPG |
| 14.number of SC-SC | 14.distance\_kurtosis of RS-SPG | 39.distance\_kurtosis of SPG-SPG |
|  | 15.distance\_entropy of RS-SPG | 40.distance\_entropy of SPG-SPG |
|  | 16.distance\_mean of RS-SC | 41.distance\_mean of SPG-SC |
|  | 17.distance\_std of RS-SC | 42.distance\_std of SPG-SC |
|  | 18.distance\_skewness of RS-SC | 43.distance\_skewness of SPG-SC |
|  | 19.distance\_kurtosis of RS-SC | 44.distance\_kurtosis of SPG-SC |
|  | 20.distance\_entropy of RS-SC | 45.distance\_entropy of SPG-SC |
|  | 21.distance\_mean of SPC-SPC | 46.distance\_mean of SC-SC |
|  | 22.distance\_std of SPC-SPC | 47.distance\_std of SC-SC |
|  | 23.distance\_skewness of SPC-SPC | 48.distance\_skewness of SC-SC |
|  | 24.distance\_kurtosis of SPC-SPC | 49.distance\_kurtosis of SC-SC |
|  | 25.distance\_entropy of SPC-SPC | 50.distance\_entropy of SC-SC |