Table 1 Per-Class Performance (Mean ± Std) for Bayesian—Scikit Optimization Across Selected K-values

K	Class	Mean Precision ± Std	Mean Recall ± Std	Mean F1 ± Std
3	Benign	0.836 ± 0.007	0.915 ± 0.007	0.874 ±0.007
	Malignant	0.920 ± 0.029	0.708 ± 0.015	0.800 ±0.005
	Normal	0.822 ± 0.027	0.873 ± 0.022	0.846 ±0.008
4	Benign	0.846 ± 0.017	0.893 ± 0.021	0.868 ±0.015
	Malignant	0.844 ± 0.051	0.757 ± 0.041	0.798 ±0.045
	Normal	0.866 ± 0.025	0.857± 0.089	0.860 ±0.056
5	Benign	0.853 ± 0.021	0.841 ± 0.062	0.846 ±0.026
	Malignant	0.781 ± 0.108	0.762 ± 0.047	0.766 ±0.046
	Normal	0.791 ± 0.104	0.800 ± 0.070	0.787 ±0.029
6	Benign	0.846 ± 0.012	0.878 ± 0.027	0.862 ±0.016
	Malignant	0.892 ± 0.050	0.760 ± 0.023	0.820 ±0.027
	Normal	0.791 ± 0.051	0.873 ± 0.044	0.827 ±0.024
7	Benign	0.833 ± 0.020	0.857 ± 0.032	0.844 ±0.013
	Malignant	0.806 ± 0.052	0.700 ± 0.058	0.746 ±0.030
	Normal	0.830 ± 0.041	0.911 ± 0.040	0.867 ±0.021
8	Benign	0.840 ± 0.024	0.861 ± 0.030	0.850 ±0.016
	Malignant	0.827 ± 0.049	0.750 ± 0.041	0.785 ±0.033
	Normal	0.823 ± 0.055	0.869 ± 0.057	0.843 ±0.046
9	Benign	0.845 ± 0.039	0.901 ± 0.045	0.871 ±0.025
	Malignant	0.885 ± 0.052	0.739 ± 0.055	0.803 ±0.029
	Normal	0.835 ± 0.058	0.862 ± 0.096	0.845 ±0.056
10	Benign	0.843 ± 0.023	0.858 ± 0.040	0.850 ±0.019
	Malignant	0.821 ± 0.064	0.743 ± 0.033	0.778 ±0.022
	Normal	0.821 ± 0.065	0.876 ± 0.044	0.844 ±0.028

Table 2 Per-Class Performance (Mean ± Std) for Bayesian—Optuna Across Selected K-values

K	Class	Mean Precision ± Std	Mean Recall ± Std	Mean F1 ± Std
3	Benign	0.846 ± 0.040	0.889 ± 0.013	0.866 ±0.021
	Malignant	0.832 ± 0.019	0.718 ± 0.051	0.770 ±0.024
	Normal	0.863 ± 0.064	0.905 ± 0.078	0.883 ±0.069
4	Benign	0.852 ± 0.012	0.917 ± 0.032	0.883 ±0.016
	Malignant	0.881 ± 0.042	0.734 ± 0.015	0.800 ±0.019
	Normal	0.885 ± 0.037	0.905 ± 0.075	0.892 ±0.038
5	Benign	0.843 ± 0.024	0.860 ± 0.055	0.850 ±0.027
	Malignant	0.848 ± 0.079	0.750 ± 0.034	0.793 ±0.030
	Normal	0.803 ± 0.090	0.866 ± 0.070	0.829 ±0.051
6	Benign	0.858 ± 0.018	0.894 ± 0.027	0.875 ±0.017
	Malignant	0.863 ± 0.066	0.760 ± 0.047	0.806 ±0.040
	Normal	0.865 ± 0.035	0.904 ± 0.048	0.883 ±0.027
7	Benign	0.848 ± 0.030	0.904 ± 0.045	0.873 ±0.013
	Malignant	0.859 ± 0.062	0.772 ± 0.043	0.810 ±0.019
	Normal	0.909 ± 0.047	0.843 ± 0.087	0.871 ±0.042
8	Benign	0.849 ± 0.016	0.871 ± 0.024	0.859 ±0.008
	Malignant	0.843 ± 0.062	0.703 ± 0.038	0.764 ±0.029

	Normal	0.798 ± 0.077	0.923 ± 0.047	0.853 ±0.056
9	Benign	0.826 ± 0.041	0.864 ± 0.032	0.844 ±0.027
	Malignant	0.794 ± 0.050	0.739 ± 0.044	0.763 ±0.013
	Normal	0.861 ± 0.062	0.820 ± 0.114	0.837 ±0.078
10	Benign	0.840 ± 0.029	0.911 ± 0.029	0.873 ±0.018
	Malignant	0.842 ± 0.047	0.743 ± 0.070	0.787 ±0.040
	Normal	0.913 ± 0.053	0.833 ± 0.071	0.870 ±0.052

Table 3 Per-Class Performance Metrics (Mean ± Std) for Bayesian——GPyOpt Across Selected K-values

K	Class	Mean Precision ± Std	Mean Recall ± Std	Mean F1 ± Std
3	Benign	0.809 ± 0.008	0.830 ± 0.040	0.819 ±0.023
	Malignant	0.693 ± 0.082	0.700 ± 0.015	0.693 ±0.048
	Normal	0.841 ± 0.034	0.746 ± 0.022	0.790 ±0.008
4	Benign	0.816 ± 0.027	0.869 ± 0.052	0.840 ±0.020
	Malignant	0.761 ± 0.079	0.710 ± 0.026	0.732 ±0.032
	Normal	0.837 ± 0.090	0.726 ± 0.021	0.774 ±0.031
5	Benign	0.841 ± 0.026	0.879 ± 0.024	0.859 ±0.002
	Malignant	0.876 ± 0.061	0.756 ± 0.041	0.809 ±0.026
	Normal	0.820 ± 0.049	0.867 ± 0.063	0.842 ±0.051
6	Benign	0.830 ± 0.020	0.886 ± 0.035	0.856 ±0.018
	Malignant	0.823 ± 0.057	0.740 ± 0.029	0.779 ±0.035
	Normal	0.860 ± 0.048	0.809 ± 0.080	0.831 ±0.050
7	Benign	0.831 ± 0.028	0.884 ± 0.048	0.856 ±0.017
	Malignant	0.813 ± 0.072	0.754 ± 0.045	0.780 ±0.031
	Normal	0.891 ± 0.035	0.796 ± 0.100	0.835 ±0.045
8	Benign	0.826 ± 0.022	0.897 ± 0.041	0.860 ±0.025
	Malignant	0.842 ± 0.083	0.730 ± 0.038	0.780 ±0.051
	Normal	0.862 ± 0.060	0.803 ± 0.044	0.831 ±0.046
9	Benign	0.857 ± 0.026	0.880 ± 0.043	0.867 ±0.019
	Malignant	0.872 ± 0.078	0.729 ± 0.059	0.789 ±0.022
	Normal	0.817 ± 0.078	0.925 ± 0.068	0.863 ±0.041
10	Benign	0.849 ± 0.029	0.874 ± 0.053	0.860 ±0.020
	Malignant	0.822 ± 0.084	0.740 ± 0.044	0.774 ±0.033
	Normal	0.856 ± 0.053	0.881 ± 0.049	0.866 ±0.034

Table 4 Per-Class Performance Metrics (Mean ± Std) for TPE——Optuna Across Selected K-values

K	Class	Mean Precision ± Std	Mean Recall ± Std	Mean F1 ± Std
3	Benign	0.845± 0.006	0.894 ± 0.027	0.868 ±0.014
	Malignant	0.897 ± 0.044	0.708 ± 0.015	0.790 ±0.008
	Normal	0.795 ± 0.052	0.905 ± 0.039	0.845 ±0.026
4	Benign	0.859 ± 0.012	0.865 ± 0.053	0.860 ±0.021
	Malignant	0.869 ± 0.065	0.734 ± 0.047	0.793 ±0.026
	Normal	0.801 ± 0.073	0.952 ± 0.033	0.867 ±0.038
5	Benign	0.834 ± 0.022	0.844 ± 0.023	0.839 ±0.013
	Malignant	0.769 ± 0.063	0.743 ± 0.023	0.754 ±0.020
	Normal	0.842 ± 0.056	0.838 ± 0.023	0.839 ±0.029
6	Benign	0.857 ± 0.025	0.910 ± 0.035	0.881 ±0.012
	Malignant	0.840 ± 0.077	0.770 ± 0.029	0.801 ±0.032

	Normal	0.910 ± 0.022	0.841 ± 0.065	0.874 ±0.038
7	Benign	0.832 ± 0.032	0.868 ± 0.041	0.849 ±0.016
	Malignant	0.846 ± 0.061	0.723 ± 0.035	0.779 ±0.040
	Normal	0.819 ± 0.097	0.870 ± 0.079	0.837 ±0.049
8	Benign	0.839 ± 0.024	0.865 ± 0.050	0.851 ±0.021
	Malignant	0.831 ± 0.067	0.730 ± 0.038	0.774 ±0.021
	Normal	0.829 ± 0.063	0.886 ± 0.063	0.854 ±0.041
9	Benign	0.846 ± 0.015	0.901 ± 0.018	0.872 ±0.013
	Malignant	0.872 ± 0.049	0.736 ± 0.030	0.797 ±0.017
	Normal	0.854 ± 0.049	0.884 ± 0.068	0.867 ±0.041
10	Benign	0.839 ± 0.022	0.879 ± 0.039	0.857 ±0.012
	Malignant	0.811 ± 0.074	0.721 ± 0.026	0.762 ±0.037
	Normal	0.835 ± 0.081	0.838 ± 0.077	0.834 ±0.064

Table 5 Per-Class Performance Metrics (Mean ± Std) for TPE—Hyperopt Across Selected K-values

K	Class	Mean Precision ± Std	Mean Recall ± Std	Mean F1 ± Std
3	Benign	0.885± 0.030	0.831 ± 0.060	0.854 ±0.023
	Malignant	0.767± 0.066	0.802 ± 0.078	0.778 ±0.011
	Normal	0.867 ± 0.003	0.936 ± 0.022	0.900 ±0.012
4	Benign	0.849 ± 0.025	0.889 ± 0.011	0.868 ±0.017
	Malignant	0.820 ± 0.039	0.734 ± 0.034	0.774 ±0.017
	Normal	0.872 ± 0.048	0.881 ± 0.023	0.876 ±0.033
5	Benign	0.832 ± 0.011	0.882 ± 0.024	0.856 ±0.015
	Malignant	0.857 ± 0.038	0.693 ± 0.046	0.764 ±0.022
	Normal	0.794 ± 0.058	0.876 ± 0.071	0.832 ±0.057
6	Benign	0.855 ± 0.019	0.904 ± 0.029	0.879 ±0.020
	Malignant	0.864 ± 0.065	0.775 ± 0.028	0.804 ±0.027
	Normal	0.885 ± 0.058	0.889 ± 0.035	0.886 ±0.039
7	Benign	0.824 ± 0.025	0.897 ± 0.033	0.858 ±0.014
	Malignant	0.876 ± 0.086	0.723 ± 0.039	0.789 ±0.037
	Normal	0.827 ± 0.047	0.809 ± 0.056	0.817 ±0.043
8	Benign	0.840 ± 0.021	0.865 ± 0.025	0.852 ±0.019
	Malignant	0.840 ± 0.053	0.734 ± 0.031	0.781 ±0.022
	Normal	0.816 ± 0.054	0.892 ± 0.066	0.852 ±0.054
9	Benign	0.841 ± 0.021	0.839 ± 0.045	0.839 ±0.020
	Malignant	0.813 ± 0.063	0.708 ± 0.055	0.754 ±0.032
	Normal	0.787 ± 0.084	0.915 ± 0.062	0.840 ±0.044
10	Benign	0.858 ± 0.035	0.890 ± 0.039	0.872 ±0.016
	Malignant	0.837 ± 0.065	0.747 ± 0.043	0.787 ±0.023
	Normal	0.853 ± 0.060	0.871 ± 0.071	0.858 ±0.038