

Table 1. Macro Performance Metrics for Bayesian—Scikit Optimization

K	Mean Accuracy \pm Std	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	0.851 \pm 0.004	0.859 \pm 0.003	0.832 \pm 0.004	0.840 \pm 0.001
4	0.849 \pm 0.019	0.852 \pm 0.022	0.836 \pm 0.024	0.842 \pm 0.021
5	0.812 \pm 0.030	0.809 \pm 0.048	0.801 \pm 0.021	0.800 \pm 0.030
6	0.844 \pm 0.017	0.843 \pm 0.021	0.837 \pm 0.015	0.836 \pm 0.016
7	0.824 \pm 0.015	0.823 \pm 0.020	0.823 \pm 0.020	0.819 \pm 0.017
8	0.831 \pm 0.016	0.830 \pm 0.018	0.827 \pm 0.022	0.826 \pm 0.017
9	0.850 \pm 0.028	0.855 \pm 0.030	0.834 \pm 0.041	0.840 \pm 0.033
10	0.830 \pm 0.020	0.830 \pm 0.030	0.826 \pm 0.019	0.824 \pm 0.021

Table 2. Per-Class Performance Metrics for Bayesian—Scikit Optimization

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

Table 3. Macro Performance Metrics for Bayesian—Optuna

K	Mean Accuracy \pm Std	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	0.845 \pm 0.025	0.847 \pm 0.024	0.837 \pm 0.038	0.840 \pm 0.031
4	0.864 \pm 0.017	0.873 \pm 0.025	0.852 \pm 0.023	0.859 \pm 0.020
5	0.831 \pm 0.025	0.832 \pm 0.031	0.827 \pm 0.025	0.824 \pm 0.025
6	0.859 \pm 0.022	0.862 \pm 0.025	0.853 \pm 0.024	0.855 \pm 0.022
7	0.857 \pm 0.014	0.872 \pm 0.023	0.840 \pm 0.028	0.852 \pm 0.017
8	0.834 \pm 0.010	0.830 \pm 0.015	0.832 \pm 0.012	0.826 \pm 0.015
9	0.822 \pm 0.028	0.827 \pm 0.029	0.808 \pm 0.041	0.815 \pm 0.033
10	0.851 \pm 0.022	0.865 \pm 0.026	0.829 \pm 0.030	0.843 \pm 0.027

Table 4. Per-Class Performance Metrics for Bayesian—Optuna

K	Class	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	Benign	0.846 \pm 0.040	0.889 \pm 0.013	0.866 \pm 0.021
	Malignant	0.832 \pm 0.019	0.718 \pm 0.051	0.770 \pm 0.024
	Normal	0.863 \pm 0.064	0.905 \pm 0.078	0.883 \pm 0.069
4	Benign	0.852 \pm 0.012	0.917 \pm 0.032	0.883 \pm 0.016
	Malignant	0.881 \pm 0.042	0.734 \pm 0.015	0.800 \pm 0.019
	Normal	0.885 \pm 0.037	0.905 \pm 0.075	0.892 \pm 0.038
5	Benign	0.843 \pm 0.024	0.860 \pm 0.055	0.850 \pm 0.027
	Malignant	0.848 \pm 0.079	0.750 \pm 0.034	0.793 \pm 0.030
	Normal	0.803 \pm 0.090	0.866 \pm 0.070	0.829 \pm 0.051
6	Benign	0.858 \pm 0.018	0.894 \pm 0.027	0.875 \pm 0.017
	Malignant	0.863 \pm 0.066	0.760 \pm 0.047	0.806 \pm 0.040
	Normal	0.865 \pm 0.035	0.904 \pm 0.048	0.883 \pm 0.027
7	Benign	0.848 \pm 0.030	0.904 \pm 0.045	0.873 \pm 0.013
	Malignant	0.859 \pm 0.062	0.772 \pm 0.043	0.810 \pm 0.019
	Normal	0.909 \pm 0.047	0.843 \pm 0.087	0.871 \pm 0.042
8	Benign	0.849 \pm 0.016	0.871 \pm 0.024	0.859 \pm 0.008
	Malignant	0.843 \pm 0.062	0.703 \pm 0.038	0.764 \pm 0.029
	Normal	0.798 \pm 0.077	0.923 \pm 0.047	0.853 \pm 0.056
9	Benign	0.826 \pm 0.041	0.864 \pm 0.032	0.844 \pm 0.027
	Malignant	0.794 \pm 0.050	0.739 \pm 0.044	0.763 \pm 0.013
	Normal	0.861 \pm 0.062	0.820 \pm 0.114	0.837 \pm 0.078
10	Benign	0.840 \pm 0.029	0.911 \pm 0.029	0.873 \pm 0.018
	Malignant	0.842 \pm 0.047	0.743 \pm 0.070	0.787 \pm 0.040
	Normal	0.913 \pm 0.053	0.833 \pm 0.071	0.870 \pm 0.052

Table 5. Macro Performance Metrics for Bayesian—GPyOpt

K	Mean Accuracy \pm Std	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	0.778 \pm 0.027	0.781 \pm 0.019	0.758 \pm 0.022	0.767 \pm 0.022
4	0.800 \pm 0.019	0.804 \pm 0.041	0.769 \pm 0.007	0.782 \pm 0.019
5	0.843 \pm 0.006	0.845 \pm 0.004	0.834 \pm 0.022	0.840 \pm 0.012
6	0.831 \pm 0.016	0.838 \pm 0.021	0.812 \pm 0.024	0.822 \pm 0.019
7	0.832 \pm 0.018	0.845 \pm 0.026	0.812 \pm 0.029	0.823 \pm 0.020
8	0.834 \pm 0.030	0.843 \pm 0.034	0.810 \pm 0.029	0.824 \pm 0.031
9	0.846 \pm 0.020	0.849 \pm 0.029	0.845 \pm 0.025	0.840 \pm 0.022
10	0.838 \pm 0.020	0.842 \pm 0.028	0.832 \pm 0.017	0.834 \pm 0.018

Table 6. Per-Class Performance Metrics for Bayesian—GPyOpt

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

Table 7. Macro Performance Metrics for TPE—Optuna

K	Mean Accuracy \pm Std	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	0.844 \pm 0.014	0.846 \pm 0.021	0.835 \pm 0.013	0.834 \pm 0.014
4	0.844 \pm 0.018	0.843 \pm 0.028	0.851 \pm 0.004	0.840 \pm 0.017
5	0.816 \pm 0.008	0.815 \pm 0.014	0.809 \pm 0.007	0.810 \pm 0.008
6	0.859 \pm 0.018	0.871 \pm 0.022	0.841 \pm 0.022	0.852 \pm 0.019
7	0.828 \pm 0.015	0.833 \pm 0.026	0.821 \pm 0.023	0.822 \pm 0.014
8	0.831 \pm 0.019	0.833 \pm 0.028	0.827 \pm 0.022	0.827 \pm 0.021
9	0.852 \pm 0.017	0.858 \pm 0.024	0.840 \pm 0.023	0.845 \pm 0.023
10	0.828 \pm 0.021	0.828 \pm 0.032	0.813 \pm 0.025	0.818 \pm 0.026

Table 8. Per-Class Performance Metrics for TPE—Optuna

K	Class	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	Benign	0.845 \pm 0.006	0.894 \pm 0.027	0.868 \pm 0.014
	Malignant	0.897 \pm 0.044	0.708 \pm 0.015	0.790 \pm 0.008
	Normal	0.795 \pm 0.052	0.905 \pm 0.039	0.845 \pm 0.026
4	Benign	0.859 \pm 0.012	0.865 \pm 0.053	0.860 \pm 0.021
	Malignant	0.869 \pm 0.065	0.734 \pm 0.047	0.793 \pm 0.026
	Normal	0.801 \pm 0.073	0.952 \pm 0.033	0.867 \pm 0.038
5	Benign	0.834 \pm 0.022	0.844 \pm 0.023	0.839 \pm 0.013
	Malignant	0.769 \pm 0.063	0.743 \pm 0.023	0.754 \pm 0.020
	Normal	0.842 \pm 0.056	0.838 \pm 0.023	0.839 \pm 0.029
6	Benign	0.857 \pm 0.025	0.910 \pm 0.035	0.881 \pm 0.012
	Malignant	0.840 \pm 0.077	0.770 \pm 0.029	0.801 \pm 0.032
	Normal	0.910 \pm 0.022	0.841 \pm 0.065	0.874 \pm 0.038
7	Benign	0.832 \pm 0.032	0.868 \pm 0.041	0.849 \pm 0.016
	Malignant	0.846 \pm 0.061	0.723 \pm 0.035	0.779 \pm 0.040
	Normal	0.819 \pm 0.097	0.870 \pm 0.079	0.837 \pm 0.049
8	Benign	0.839 \pm 0.024	0.865 \pm 0.050	0.851 \pm 0.021
	Malignant	0.831 \pm 0.067	0.730 \pm 0.038	0.774 \pm 0.021
	Normal	0.829 \pm 0.063	0.886 \pm 0.063	0.854 \pm 0.041
9	Benign	0.846 \pm 0.015	0.901 \pm 0.018	0.872 \pm 0.013
	Malignant	0.872 \pm 0.049	0.736 \pm 0.030	0.797 \pm 0.017
	Normal	0.854 \pm 0.049	0.884 \pm 0.068	0.867 \pm 0.041
10	Benign	0.839 \pm 0.022	0.879 \pm 0.039	0.857 \pm 0.012
	Malignant	0.811 \pm 0.074	0.721 \pm 0.026	0.762 \pm 0.037
	Normal	0.835 \pm 0.081	0.838 \pm 0.077	0.834 \pm 0.064

Table 9. Macro Performance Metrics for TPE—Hyperopt

K	Mean Accuracy \pm Std	Mean Precision \pm Std	Mean Recall \pm Std	Mean F1 \pm Std
3	0.842 \pm 0.018	0.840 \pm 0.015	0.856 \pm 0.009	0.844 \pm 0.014
4	0.844 \pm 0.015	0.847 \pm 0.016	0.834 \pm 0.017	0.839 \pm 0.017
5	0.829 \pm 0.014	0.828 \pm 0.022	0.817 \pm 0.018	0.818 \pm 0.018
6	0.861 \pm 0.021	0.868 \pm 0.026	0.850 \pm 0.021	0.856 \pm 0.023
7	0.833 \pm 0.018	0.843 \pm 0.025	0.810 \pm 0.024	0.822 \pm 0.020
8	0.834 \pm 0.024	0.832 \pm 0.029	0.831 \pm 0.029	0.829 \pm 0.028
9	0.817 \pm 0.022	0.813 \pm 0.022	0.821 \pm 0.024	0.811 \pm 0.025
10	0.847 \pm 0.020	0.849 \pm 0.030	0.836 \pm 0.028	0.839 \pm 0.024

Table 10. Per-Class Performance Metrics for TPE—Hyperopt

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