

Supplementary Table S3. Feature importance of the Random Trees tumor-cell classifiers

Complete feature-importance rankings as reported by QuPath. DAB-derived features were excluded from training so that tumor-cell identification is independent of p53 staining intensity.

(A) InstanSeg classifier (83 features; trained with 539 labeled cells)

Rank	Importance	Feature
1	0.0238	Min diameter μm
2	0.0196	Area μm^2
3	0.0170	ROI: 1.00 μm per pixel: OD Sum: Haralick Sum entropy (F7)
4	0.0157	Length μm
5	0.0156	ROI: 1.00 μm per pixel: OD Sum: Haralick Entropy (F8)
6	0.0143	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Information measure of correlation 1 (F11)
7	0.0139	Max diameter μm
8	0.0139	ROI: 1.00 μm per pixel: OD Sum: Haralick Angular second moment (F0)
9	0.0135	ROI: 1.00 μm per pixel: OD Sum: Haralick Difference entropy (F10)
10	0.0129	ROI: 1.00 μm per pixel: OD Sum: Mean
11	0.0129	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Entropy (F8)
12	0.0128	ROI: 1.00 μm per pixel: OD Sum: Haralick Difference variance (F9)
13	0.0126	Circularity
14	0.0124	ROI: 2.00 μm per pixel: OD Sum: Mean
15	0.0123	ROI: 1.00 μm per pixel: OD Sum: Max
16	0.0122	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Angular second moment (F0)
17	0.0120	Solidity
18	0.0119	Hematoxylin: Std.Dev.
19	0.0119	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Contrast (F1)
20	0.0118	ROI: 2.00 μm per pixel: Hematoxylin: Median
21	0.0118	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Angular second moment (F0)
22	0.0118	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Sum variance (F6)
23	0.0118	ROI: 2.00 μm per pixel: OD Sum: Median
24	0.0118	ROI: 1.00 μm per pixel: OD Sum: Haralick Sum average (F5)
25	0.0118	ROI: 1.00 μm per pixel: OD Sum: Haralick Information measure of correlation 1 (F11)
26	0.0118	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Sum average (F5)
27	0.0118	ROI: 2.00 μm per pixel: OD Sum: Max
28	0.0117	ROI: 1.00 μm per pixel: OD Sum: Median

Rank	Importance	Feature
29	0.0117	ROI: 1.00 μm per pixel: Hematoxylin: Std.dev.
30	0.0117	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Sum of squares (F3)
31	0.0117	ROI: 1.00 μm per pixel: OD Sum: Haralick Sum of squares (F3)
32	0.0116	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Inverse difference moment (F4)
33	0.0116	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Information measure of correlation 2 (F12)
34	0.0116	Hematoxylin: Median
35	0.0116	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Difference variance (F9)
36	0.0116	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Sum average (F5)
37	0.0116	ROI: 1.00 μm per pixel: OD Sum: Haralick Sum variance (F6)
38	0.0116	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Difference entropy (F10)
39	0.0116	ROI: 2.00 μm per pixel: OD Sum: Haralick Difference variance (F9)
40	0.0115	Hematoxylin: Max
41	0.0115	ROI: 2.00 μm per pixel: OD Sum: Haralick Angular second moment (F0)
42	0.0115	ROI: 2.00 μm per pixel: Hematoxylin: Mean
43	0.0115	ROI: 2.00 μm per pixel: OD Sum: Haralick Difference entropy (F10)
44	0.0115	ROI: 2.00 μm per pixel: Hematoxylin: Min
45	0.0115	ROI: 1.00 μm per pixel: Hematoxylin: Median
46	0.0114	ROI: 2.00 μm per pixel: Hematoxylin: Std.dev.
47	0.0114	ROI: 2.00 μm per pixel: Hematoxylin: Max
48	0.0114	ROI: 1.00 μm per pixel: OD Sum: Haralick Inverse difference moment (F4)
49	0.0114	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Sum variance (F6)
50	0.0113	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Difference variance (F9)
51	0.0113	ROI: 1.00 μm per pixel: Hematoxylin: Min
52	0.0113	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Contrast (F1)
53	0.0113	ROI: 2.00 μm per pixel: OD Sum: Std.dev.
54	0.0113	ROI: 1.00 μm per pixel: OD Sum: Min
55	0.0113	ROI: 1.00 μm per pixel: OD Sum: Haralick Correlation (F2)
56	0.0113	ROI: 2.00 μm per pixel: OD Sum: Min
57	0.0113	ROI: 2.00 μm per pixel: OD Sum: Haralick Contrast (F1)
58	0.0113	Hematoxylin: Mean
59	0.0113	ROI: 1.00 μm per pixel: OD Sum: Haralick Contrast (F1)

Rank	Importance	Feature
60	0.0113	ROI: 1.00 μm per pixel: Hematoxylin: Max
61	0.0113	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Difference entropy (F10)
62	0.0113	ROI: 2.00 μm per pixel: OD Sum: Haralick Sum average (F5)
63	0.0113	ROI: 2.00 μm per pixel: OD Sum: Haralick Sum variance (F6)
64	0.0113	ROI: 2.00 μm per pixel: OD Sum: Haralick Sum entropy (F7)
65	0.0113	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Inverse difference moment (F4)
66	0.0112	ROI: 1.00 μm per pixel: OD Sum: Haralick Information measure of correlation 2 (F12)
67	0.0112	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Information measure of correlation 2 (F12)
68	0.0112	ROI: 2.00 μm per pixel: OD Sum: Haralick Correlation (F2)
69	0.0111	ROI: 1.00 μm per pixel: OD Sum: Std.dev.
70	0.0111	ROI: 1.00 μm per pixel: Hematoxylin: Mean
71	0.0111	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Sum entropy (F7)
72	0.0111	ROI: 2.00 μm per pixel: OD Sum: Haralick Information measure of correlation 1 (F11)
73	0.0111	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Correlation (F2)
74	0.0111	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Information measure of correlation 1 (F11)
75	0.0111	Hematoxylin: Min
76	0.0110	ROI: 2.00 μm per pixel: OD Sum: Haralick Inverse difference moment (F4)
77	0.0110	ROI: 2.00 μm per pixel: OD Sum: Haralick Sum of squares (F3)
78	0.0110	ROI: 2.00 μm per pixel: OD Sum: Haralick Information measure of correlation 2 (F12)
79	0.0110	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Sum of squares (F3)
80	0.0110	ROI: 1.00 μm per pixel: Hematoxylin: Haralick Correlation (F2)
81	0.0110	ROI: 2.00 μm per pixel: OD Sum: Haralick Entropy (F8)
82	0.0110	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Sum entropy (F7)
83	0.0109	ROI: 2.00 μm per pixel: Hematoxylin: Haralick Entropy (F8)

(B) Legacy watershed classifier (95 features)

Rank	Importance	Feature
1	0.0140	Nucleus/Cell area ratio
2	0.0129	Cell: Hematoxylin OD mean
3	0.0113	Nucleus: Hematoxylin OD std dev
4	0.0113	Nucleus: Min caliper
5	0.0112	Nucleus: 1.00 μm per pixel: OD Sum: Median

Rank	Importance	Feature
6	0.0112	Nucleus: 1.00 µm per pixel: OD Sum: Max
7	0.0112	Nucleus: 1.00 µm per pixel: OD Sum: Std.dev.
8	0.0111	Nucleus: Hematoxylin OD max
9	0.0111	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Information measure of correlation 1 (F11)
10	0.0110	Nucleus: Eccentricity
11	0.0110	Nucleus: 1.00 µm per pixel: Hematoxylin: Mean
12	0.0109	Nucleus: Hematoxylin OD mean
13	0.0109	Cell: Hematoxylin OD min
14	0.0109	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Sum average (F5)
15	0.0109	Cell: Hematoxylin OD std dev
16	0.0108	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Sum of squares (F3)
17	0.0108	Nucleus: Area
18	0.0108	Cell: Area
19	0.0108	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Sum entropy (F7)
20	0.0108	Nucleus: Hematoxylin OD range
21	0.0107	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Contrast (F1)
22	0.0107	Cell: Hematoxylin OD max
23	0.0107	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Information measure of correlation 1 (F11)
24	0.0107	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Correlation (F2)
25	0.0107	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Sum of squares (F3)
26	0.0106	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Information measure of correlation 2 (F12)
27	0.0106	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Angular second moment (F0)
28	0.0106	Nucleus: 1.00 µm per pixel: OD Sum: Mean
29	0.0106	Nucleus: 1.00 µm per pixel: Hematoxylin: Median
30	0.0106	Nucleus: 1.00 µm per pixel: OD Sum: Haralick Entropy (F8)
31	0.0106	Nucleus: 1.00 µm per pixel: Hematoxylin: Min
32	0.0106	Nucleus: 1.00 µm per pixel: Hematoxylin: Max
33	0.0105	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Correlation (F2)
34	0.0105	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Sum variance (F6)
35	0.0105	Nucleus: 1.00 µm per pixel: Hematoxylin: Haralick Sum entropy (F7)

Rank	Importance	Feature
36	0.0105	Nucleus: 2.00 μm per pixel: Hematoxylin: Std.dev.
37	0.0105	Nucleus: 2.00 μm per pixel: Hematoxylin: Max
38	0.0105	Cell: Min caliper
39	0.0105	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Sum entropy (F7)
40	0.0105	Nucleus: Hematoxylin OD sum
41	0.0105	Nucleus: 1.00 μm per pixel: Hematoxylin: Haralick Sum average (F5)
42	0.0105	Nucleus: 1.00 μm per pixel: Hematoxylin: Haralick Inverse difference moment (F4)
43	0.0104	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Difference variance (F9)
44	0.0104	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Sum variance (F6)
45	0.0104	Nucleus: 1.00 μm per pixel: Hematoxylin: Haralick Angular second moment (F0)
46	0.0104	Nucleus: Max caliper
47	0.0104	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Sum average (F5)
48	0.0104	Nucleus: 2.00 μm per pixel: Hematoxylin: Median
49	0.0104	Nucleus: 2.00 μm per pixel: OD Sum: Mean
50	0.0104	Nucleus: 1.00 μm per pixel: OD Sum: Min
51	0.0104	Nucleus: 1.00 μm per pixel: OD Sum: Haralick Difference variance (F9)
52	0.0104	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Inverse difference moment (F4)
53	0.0104	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Sum of squares (F3)
54	0.0104	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Sum variance (F6)
55	0.0104	Nucleus: 2.00 μm per pixel: OD Sum: Max
56	0.0104	Nucleus: 1.00 μm per pixel: OD Sum: Haralick Contrast (F1)
57	0.0103	Nucleus: 1.00 μm per pixel: Hematoxylin: Haralick Difference variance (F9)
58	0.0103	Nucleus: 1.00 μm per pixel: OD Sum: Haralick Difference entropy (F10)
59	0.0103	Nucleus: 1.00 μm per pixel: OD Sum: Haralick Sum variance (F6)
60	0.0103	Nucleus: Circularity
61	0.0103	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Information measure of correlation 2 (F12)
62	0.0103	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Information measure of correlation 2 (F12)
63	0.0103	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Difference variance (F9)
64	0.0103	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Sum average (F5)
65	0.0103	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Contrast (F1)

Rank	Importance	Feature
66	0.0103	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Difference entropy (F10)
67	0.0103	Nucleus: 2.00 μm per pixel: OD Sum: Median
68	0.0102	Nucleus: 1.00 μm per pixel: Hematoxylin: Haralick Difference entropy (F10)
69	0.0102	Cell: Max caliper
70	0.0102	Nucleus: 1.00 μm per pixel: Hematoxylin: Haralick Entropy (F8)
71	0.0102	Nucleus: 2.00 μm per pixel: Hematoxylin: Min
72	0.0102	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Contrast (F1)
73	0.0102	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Information measure of correlation 1 (F11)
74	0.0102	Cell: Perimeter
75	0.0102	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Correlation (F2)
76	0.0102	Nucleus: Perimeter
77	0.0102	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Inverse difference moment (F4)
78	0.0102	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Sum of squares (F3)
79	0.0102	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Entropy (F8)
80	0.0102	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Sum entropy (F7)
81	0.0101	Nucleus: 2.00 μm per pixel: Hematoxylin: Haralick Angular second moment (F0)
82	0.0101	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Entropy (F8)
83	0.0101	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Difference entropy (F10)
84	0.0101	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Information measure of correlation 1 (F11)
85	0.0101	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Correlation (F2)
86	0.0101	Nucleus: 2.00 μm per pixel: OD Sum: Min
87	0.0101	Cell: Eccentricity
88	0.0101	Nucleus: Hematoxylin OD min
89	0.0100	Nucleus: 1.00 μm per pixel: OD Sum: Haralick Information measure of correlation 2 (F12)
90	0.0100	Nucleus: 2.00 μm per pixel: OD Sum: Std.dev.
91	0.0100	Nucleus: 2.00 μm per pixel: Hematoxylin: Mean
92	0.0100	Nucleus: 1.00 μm per pixel: OD Sum: Haralick Inverse difference moment (F4)
93	0.0100	Nucleus: 2.00 μm per pixel: OD Sum: Haralick Angular second moment (F0)
94	0.0099	Nucleus: 1.00 μm per pixel: Hematoxylin: Std.dev.
95	0.0099	Cell: Circularity

^aClassifiers were trained interactively (expert-in-the-loop) in QuPath v0.7.0 with a Random Trees model; a pathologist labeled representative cells and reviewed the live classification. Separate classifiers were built in independent QuPath projects for the two detection algorithms and are not interchangeable.

^bThe feature set comprised hematoxylin optical density, nuclear and cell morphometry, and Haralick texture features computed at 1 and 2 micrometers per pixel. All DAB-derived features were excluded.

^cFor InstanSeg, nuclear size (minimum diameter, area) and 1 micrometer per pixel optical-density-sum texture features contributed most; for the legacy detector, nuclear and cell shape (area ratio, caliper, eccentricity) and hematoxylin optical density contributed most.