Supplementary Materials

Oocytor: features list

Oocyte Features		
Name	Type	Description
OoArea	Size	Oocyte cytoplasm area A
OoMajorAxisLength	Size	Cortex (fitting ellipse) major axis maj
OoMinorAxisLength	Size	Cortex (fitting ellipse) minor axis min
OoFeretDiam	Size	Cortex feret's diameter
OoPerimeter	Size	Cortex perimeter p
OoEllAspectRatio	Shape	cortex maj/min
OoCircularity	Shape	Cortex $4\pi * A/p^2$
OoRoundness	Shape	Cortex $4A/(\pi maj^2)$
OoConvexity	Shape	(solidity) difference to convex hull A/A_{hull}
OoCurvatureMean	Shape	Mean absolute curvature ($k = \frac{\lvert x'y'' - y'x''\rvert}{(x'^2 + y'^2)^{3/2}}$) [4]
OoCurvatureStd	Shape	Standard deviation of curvature [4]
OoCurvatureMax	Shape	Maximum value of curvature along the cortex
OoCurvatureMin	Shape	Minimum value of curvature along the cortex
OoCurvatureCoefVar	Shape	Coefficient of variation (mean/sd) of the curvature
OoCurvatureNormMean	Shape	Mean curvature normalised by the mean oocyte curvature (given its radius)
OoCurvatureNormStd	Shape	Std radius of curvature normalised by the mean oocyte curvature
OoCurvatureNormMin	Shape	Min radius of curvature normalised by the mean oocyte curvature
OoCurvatureNormMax	Shape	Max radius of curvature normalised by the mean oocyte curvature
OoCurvatureFlatProp	Shape	Proportion of cortex considered flat (k¡4*mean oocyte curvature)
OoCurvatureBendingEnergy	Shape	Bending energy of the curvature $\frac{1}{n}\sum k^2$ [4]
OoLocoEFACumDist	Shape	Cumulative distance of fitted Ellipted Fourier modes (Loco-EFA analysis), adapted from [7]
OoLocoEFAEntropy	Shape	Entropy of Loco-EFA modes L_n (complexity of the shape) [7]
OoLocoEFAMaxLnMode	Shape	Most contributing mode L_n ($n > 2$) [7]

Oocyte Features		
OoKurtosis	Intensity	Kurtosis of intensity distribution inside cytoplasm
OoNormMean	Intensity	Normalised (by mean extern intensity) mean intensity inside oocyte
OoNormStd	Intensity	Normalised (by mean extern intensity) standard deviation of intensity inside oocyte
OoNormCoefVar	Intensity	Coefficient of variation (mean/sd) of intensity inside oocyte
OoGLCMAngular2Moment	Texture	Haralick's texture measures from Gray Level Cooccurence Matrices (GLCM) G [3]: cytoplasm homogenity $\sum_i \sum_j G(i,j)^2$
OoGLCMEntropy	Texture	Haralick's texture measures from GLCM [3]: cytoplasm entropy $\sum_i \sum_j -G(i,j) * log(G(i,j))$
OoGLCMInverseDiffMoment	Texture	Haralick's texture measures from GLCM [3]: cytoplasm smoothness $\sum_i \sum_j \frac{1}{1+(i-j)^2 G(i,j)}$
OoGLCMClusterTendency	Texture	Haralick's texture measures from GLCM [3]: cytoplasm clustering tendency (grouping of pixels of same values) $\sum_i \sum_j (i+j-\mu_x-\mu_y)^2) G(i,j)$
OoGLCMClusterShade	Texture	Haralick's texture measures from GLCM [3]: cytoplasm cluster shade (skewness, asymetry of cytoplasm) $\sum_i \sum_j (i+j-\mu_x-\mu_y)^3) G(i,j)$
OoGLCMCorrelation	Texture	Haralick's texture measures from GLCM [3]: cytoplasm correlation $\sum_i \sum_j \frac{ijG(i,j)-\mu_x\mu_y}{\sigma_x\sigma_y}$
OoGLCMContrast	Texture	Haralick's texture measures from GLCM [3]: cytoplasm contrast (local variation) $\sum_i \sum_j (i-j)^2 G(i,j)$
OoGLCMHomogeneity	Texture	Haralick's texture measures from GLCM [3]: cytoplasm homogeneity, closeness of elements distributions to diagonal $\sum_i \sum_j \frac{G(i,j)}{(1+\lvert i-j\rvert)^2}$
OoGLCMVariance	Texture	Haralick's texture measures from GLCM [3]: cytoplasm variance, gray level spreading $\sum_i \sum_j (i-\mu_x)^2 G(i,j) + (j-\mu_y)^2 G(i,j)$
OoLBPMean	Texture	Mean Local Binary Pattern (LBP) value [6]. Characterisation of image texture robust compared to illumination variation
OoLBPVar	Texture	Standard deviation of LBP value [6]
OoLBPSkewness	Texture	Skewness of LBP value distribution [6]
OoLBPKurtosis	Texture	Kurtosis of LBP value distribution [6]
OoParticleNumber	Texture	Number of "particles" detected by thresholding the image of smallest eigenvalues of the Heissan of the image (obtained with FeatureJ [1] plugin)
OoParticleAverageSize	Texture	Average of of "particles" detected by thresholding the image of smallest eigenvalues of the Heissan of the image (FeatureJ plugin [1])
OoMoranIndexK5	Spatial	Spatial auto-correlation (Moran Index, [5]), with a neighboring size of 5 pixels
OoMoranIndexK20	Spatial	Spatial auto-correlation (Moran Index, [5]), with a neighboring size of 20 pixels
OoParticleDistanceMean	Spatial	Average distance to center of "particles" (small structures detected based on Hessian eigenvalues with the plugin [1]) normalised by the average radius
OoParticleDistanceStd	Spatial	Standard deviation of distances to center of "particles" (small structures detected based on Hessian eigenvalues with the plugin FeatureJ) normalised by the average radius
OoParticleDistanceCoefVar	Spatial	Coefficient of variation of distance to center of "particles"

Perivitelin space Features		
Name	Type	Description
PerivArea	Size	Perivitelline zone area (between iner TZP limit and cortex)
PerivOoAreaRatio	Size	ratio between perivitelline area and cortex area
PerivThicknessMean	Size	Perivitelin space average thickness across all angles
PerivThicknessMax	Size	Perivitelin space maximal thickness
PerivThicknessMin	Size	Perivitelin space minimal thickness
PerivThicknessStd	Size	Perivitelin space standard deviation of thickness
PerivThicknessCoefVar	Size	Perivitelin thickness coefficient of variation (mean/sd)

ZonaPellucida Features		
Name	Type	Description
ZPArea	Size	ZP area
ZPPerimIn	Size	ZP iner perimeter
ZPPerimOut	Size	ZP outer perimeter
ZPThicknessMean	Size	ZP average thickness
ZPThicknessMax	Size	ZP maximum thickness
ZPThicknessMin	Size	ZP minimum thickness
ZPThicknessStd	Size	ZP thickness variation
ZPThicknessCoefVar	Size	ZP thickness coefficient of variation (mean/sd)
ZPOoRadiusRatio	Size	mean outer ZP radius r_{TZP} compared to mean Oocyte radius $\frac{r_{TZP}}{r_{Oo}}$
ZPEllAspectRatioOut	Shape	ZP outer limit maj/min
ZPOutCurvatureMean	Shape	Mean outer curvature radius ($R = 1/k = \frac{\lvert x'y'' - y'x''\rvert}{(x'^2 + y'^2)^{3/2}}$)
ZPOutCurvatureStd	Shape	Standard deviation of outer curvature radius
ZPOutCurvatureMax	Shape	Maximum value of outer curvature radius
ZPOutCurvatureMin	Shape	Minimum value of outer curvature radius
ZPOutCurvatureNormMean	Shape	Mean value of outer curvature radius normalised by ZPOut mean radius
ZPOutCurvatureNormStd	Shape	Standard deviation of outer curvature radius, normalised
ZPOutCurvatureNormMax	Shape	Maximum value of outer curvature radius, normalised
ZPOutCurvatureNormMin	Shape	Minimum value of outer curvature radius, normalised
ZPOutCurvatureFlatProp	Shape	Proportion of outer limit considered flat (R ¿ 2*mean radius)
ZPOutCurvatureBendingEnergy	Shape	Bending energy of the curvature of the outer ZP limit $\frac{1}{n}\sum k^2$
ZPIn	Shape	Same 11 shape features for the iner limit

ZonaPellucida Features		
Name	Type	Description
ZPKurtosis	Intensity	Kurtosis of intensity distribution inside ZP
ZPNormMean	Intensity	Normalised (by mean extern intensity) mean intensity inside ZP
ZPNormStd	Intensity	Normalised (by mean extern intensity) variation of intensity inside ZP
ZPNormCoefVar	Intensity	Coefficient of variation of intensity inside ZP (mean/sd)
ZPLBPMean	Texture	Mean Local Binary Pattern (LBP) value [6]. Characterisation of image texture robust compared to illumination variation
ZPLBPVar	Texture	Standard deviation of LBP value [6]
ZPLBPSkewness	Texture	Skewness of LBP value distribution [6]
ZPLBPKurtosis	Texture	Kurtosis of LBP value distribution [6]
ZPGLCMAngular2Moment	Texture	Haralick's texture GLCM [3] ZP homogeneity
ZPGLCMEntropy	Texture	Haralick's texture measures from GLCM [3]: ZP entropy $\sum_i \sum_j -G(i,j) * log(G(i,j))$
ZPGLCMInverseDiffMoment	Texture	Haralick's texture measures from GLCM [3]: ZP smoothness $\sum_i \sum_j \frac{1}{1+(i-j)^2 G(i,j)}$
ZPGLCMClusterTendency	Texture	Haralick's texture measures from GLCM [3]: ZP clustering tendency (grouping of pixels of same values) $\sum_i \sum_j (i+j-\mu_x-\mu_y)^2) G(i,j)$
ZPGLCMClusterShade	Texture	Haralick's texture measures from GLCM [3]: ZP cluster shade (skewness, asymetry of cytoplasm) $\sum_i \sum_j (i+j-\mu_x-\mu_y)^3) G(i,j)$
ZPGLCMCorrelation	Texture	Haralick's texture measures from GLCM [3]: ZP correlation $\sum_i \sum_j \frac{ijG(i,j)-\mu_x\mu_y}{\sigma_x\sigma_y}$
ZPGLCMContrast	Texture	Haralick's texture measures from GLCM [3]: ZP contrast (local variation) $\sum_i \sum_j (i-j)^2 G(i,j)$
ZPGLCMHomogeneity	Texture	Haralick's texture measures from GLCM [3]: ZP homogeneity, closeness of elements distributions to diagonal $\sum_i \sum_j \frac{G(i,j)}{(1+\lvert i-j\rvert)^2}$
ZPGLCMVariance	Texture	Haralick's texture measures from GLCM [3]: ZP variance, gray level spreading $\sum_i \sum_j (i-\mu_x)^2 G(i,j) + (j-\mu_y)^2 G(i,j)$
ZPTubularStructure	Texture	Normalised amount of linear structures in the ZP (with Fiji Tubeness plugin)
ZPTubularStructureVertical	Texture	Amount of linear structures in the ZP which are "vertical" compared to the oocyte radial direction (detected with a Sobel filter)

Dynamic Features		
Name	Type	Description
OoPIVMean	Motion	Mean Particle Image Velocimetry (PIV), using the PIV plugin [8]
OoPIVStd	Motion	Standard deviation of PIV, using the PIV plugin [8]
OoPIVCoefVar	Motion	Coefficient of variation of the PIV
OoPIVMeanCenter	Motion	mean value of the PIV around the center (until 0.5*mean radius) of the oocyte
OoPIVMeanEdge	Motion	mean value of the PIV close to the edge (above 0.75*mean radius) of the oocyte
OoPIVAngleCenter	Motion	average value of the PIV radial direction around the center (until 0.5*mean radius) of the oocyte
OoPIVAngleEdge	Motion	mean value of the PIV radial direction close to the edge (above 0.75*mean radius) of the oocyte
OoFluctuationMean	Fluctuation	Mean cortex fluctuation (average over angle and time), adapted from [2]
OoFluctuationStd	Fluctuation	Standard deviation of cortex fluctuation (std over angle, averaged over time)
OoFluctuationPropMoving	Fluctuation	Proportion of angles at which there is a change of radius (above 0.1% of current radius). Varies between 0 (no mvt) and 1 (moving everywhere).
OoFluctuationPropGrowing	Fluctuation	Proportion of angles at which there is an increase of radius (above 0.1%).
OoFluctuationSpatialMode	Fluctuation	Mode of Fourier transform of the changes of radii at each angle (spatial variation)
OoFluctuationSpatialPower	Fluctuation	Power of Fourier transform of the changes of radii at each angle
OoFluctuationSpatialCorrLength	Fluctuation	Length of spatial correlation of raddi changes: distance at which the auto-correlation of the changes of radii is below 0.1

References

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[2] Maria Almonacid, Adel Al Jord, Stephany El-Hayek, Alice Othmani, Fanny Coulpier, Sophie Lemoine, Kei Miyamoto, Robert Grosse, Christophe Klein, Tristan Piolot, Philippe Mailly, Raphaël Voituriez, Auguste Genovesio, and Marie-Hélène Verlhac. Active Fluctuations of the Nuclear Envelope Shape the Transcriptional Dynamics in Oocytes. *Developmental Cell*, 51(2):145–157.e10, October 2019.

[3] R.M. Haralick. Statistical and structural approaches to texture. *Proceedings of the IEEE*, 67(5):786–804, 1979.

[4] Yang Mingqiang, Kpalma Kidiyo, and Ronsin Joseph. A Survey of Shape Feature Extraction Techniques. In Peng-Yeng Yin, editor, *Pattern Recognition Techniques, Technology and Applications*. InTech, November 2008.

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[6] T. Ojala, M. Pietikainen, and T. Maenpaa. Multiresolution gray-scale and rotation invariant texture classification with local binary patterns. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 24(7):971–987, July 2002.

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[8] Qingzong Tseng. *Study of multicellular architecture with controlled microenvironment*. Theses, Université Grenoble Alpes, July 2011.