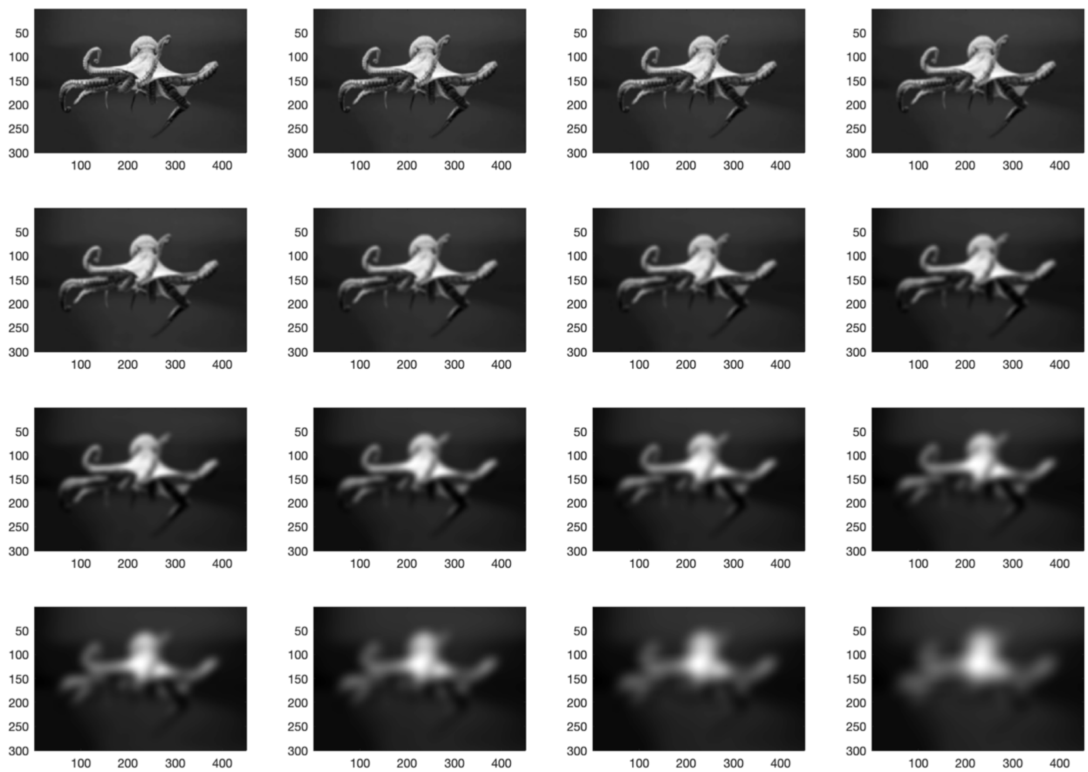
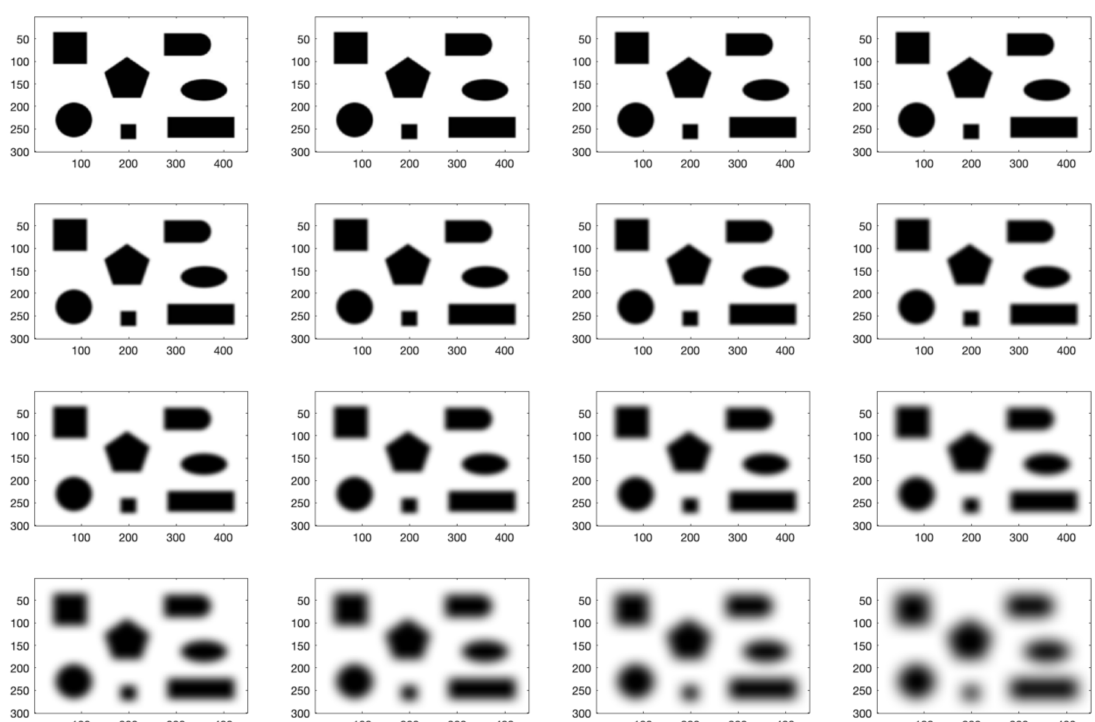
Daniel Korsunsky

Q1: Gaussian Scale Space (σ_0 = 1)

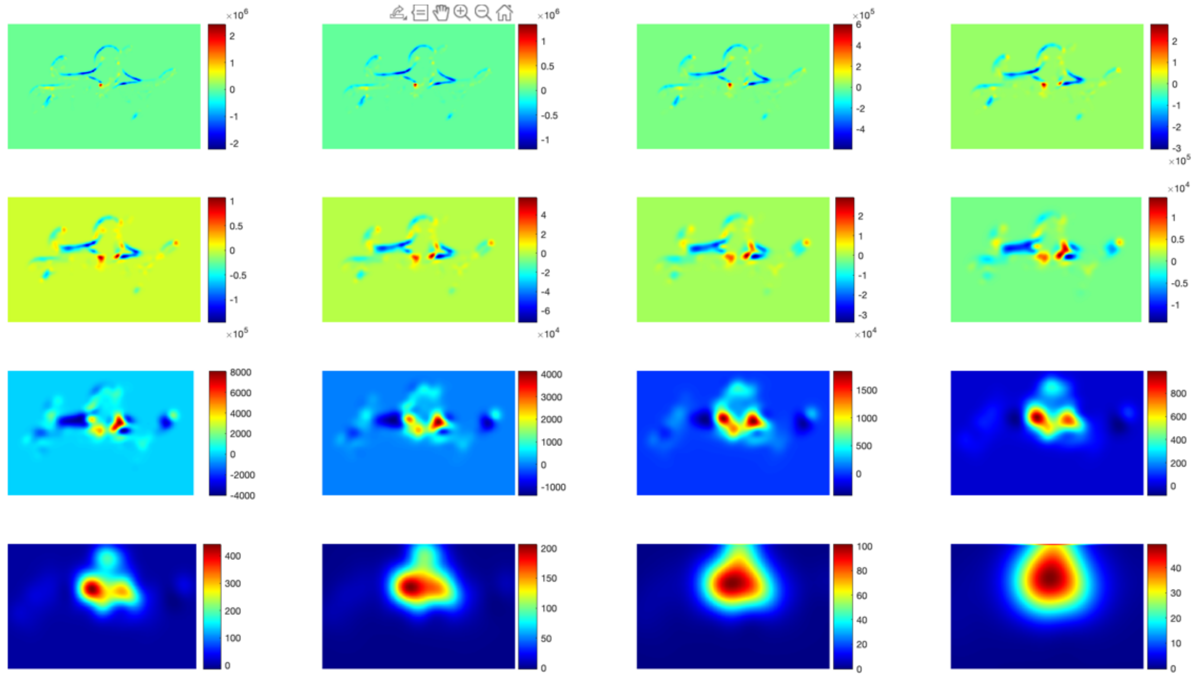


Gaussian scale space for octopus.jpg (σ_0 = 1)

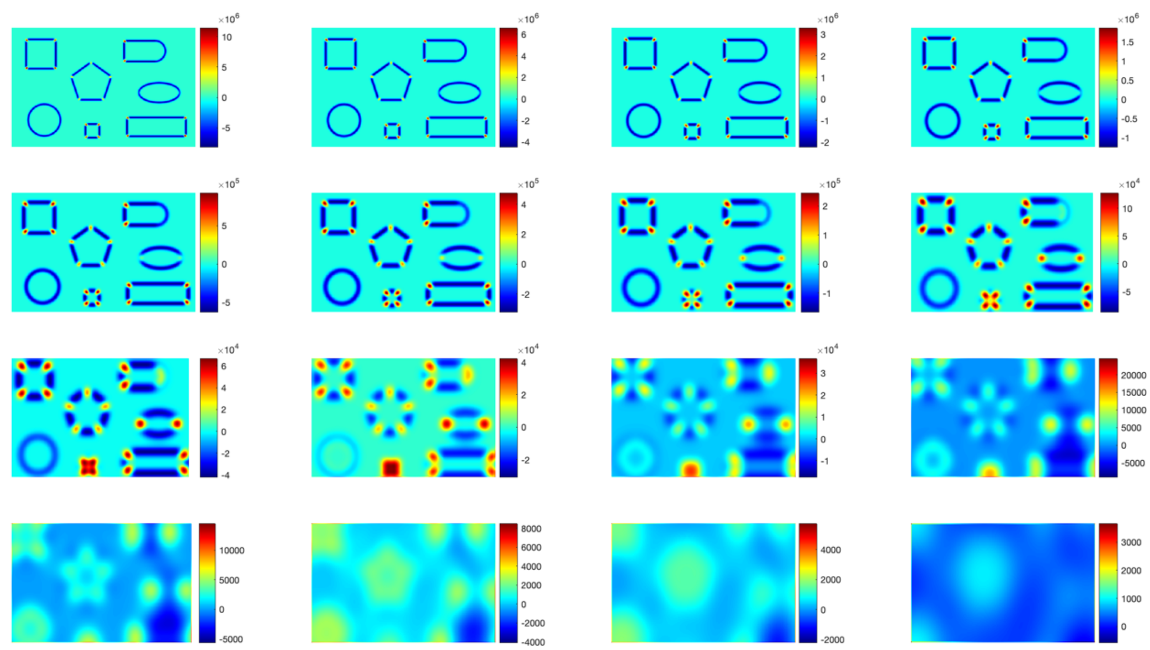


Gaussian scale space for shapes.jpg (σ_0 = 1)

Q2: Harris-Stevens



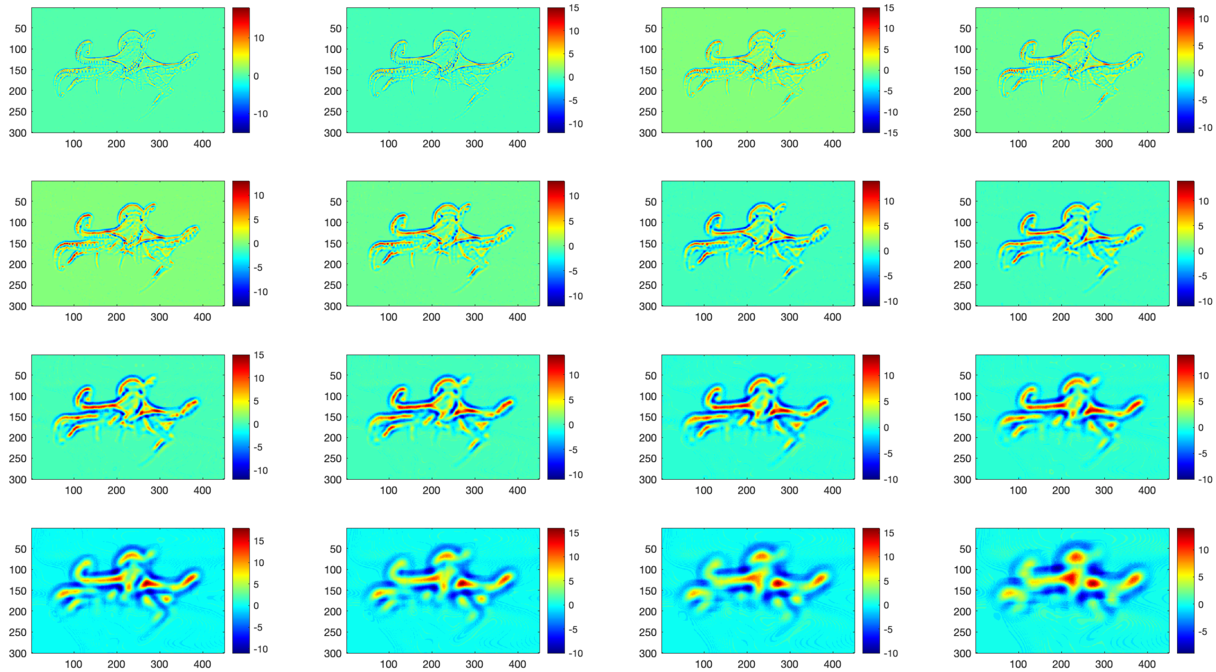
Harris-Stevens operator applied to *octopus.jpg* Gaussian scale space



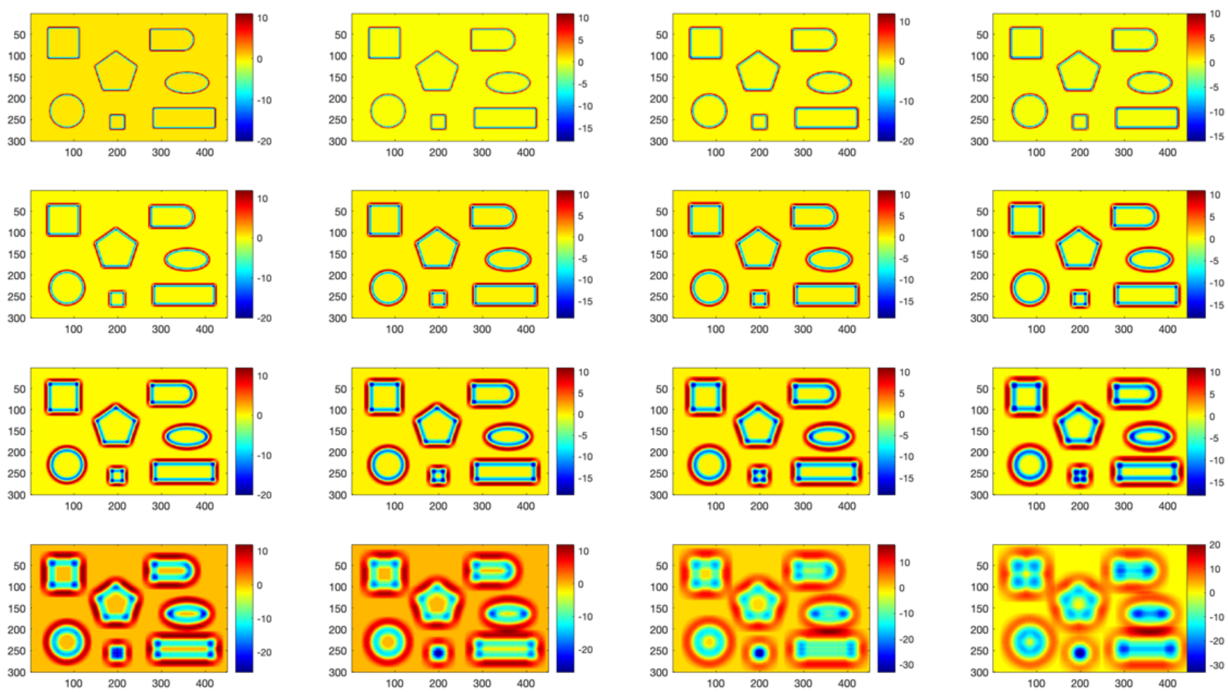
Harris-Stevens operator applied to *shapes.jpg* Gaussian scale space

As seen in the two grids, the operator does indeed highlight the locally distinctive points (LDPs). Seen more clearly in the shapes grid, the smallest operator values correspond to shape edges, while <u>the largest operator values (in shades of red) correspond to shape corners, as required</u>. In the octopus grid, small values indicate the creature's body edges and <u>large values indicate the arms' ends and bends (i.e. corners)</u>. In the shapes image, the position of the LDPs doesn't change across scale so much as their 'area' increases with image blur; LDPs that are close together merge, as in the square at the bottom of shapes.jpg. In the octopus image, in addition, as the image is blurred more, points with low operators merge to create LDPs in between them, as seen in the middle of the octopus body. As the scale becomes too big, however, the LDPs disappear. Note that the zero-point coloring changes across scales.

Q3: Difference of Gaussians



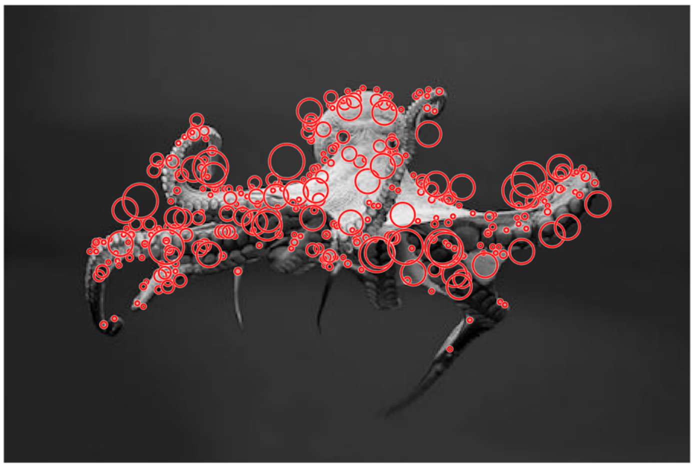
Difference of Gaussians scale space of octopus.jpg

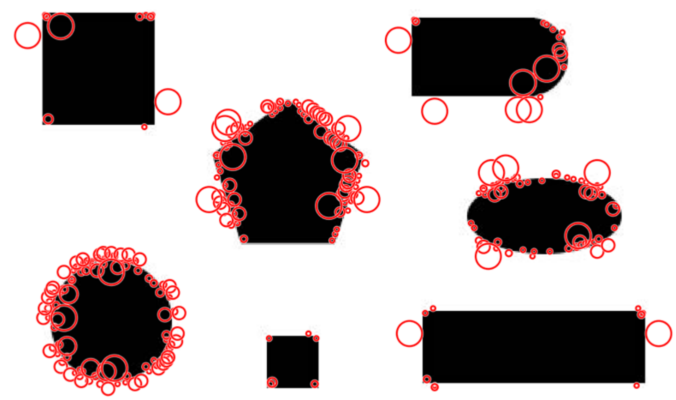


Difference of Gaussians scale space of shapes.jpg

As scale increases, zero crossings become curvier (less straight and precise) as well as spaced farther apart from each other (less dense). These features can be attributed to the increased image blurring, which produces thicker and less well-defined edges, as can be seen in the two grids above.

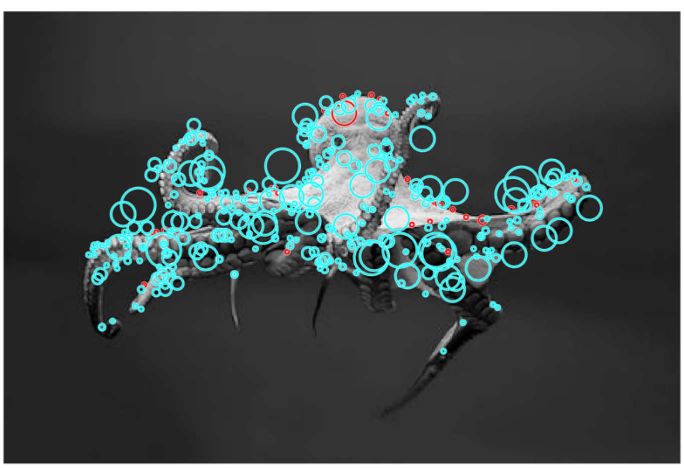
Q4: SIFT Keypoint Detection

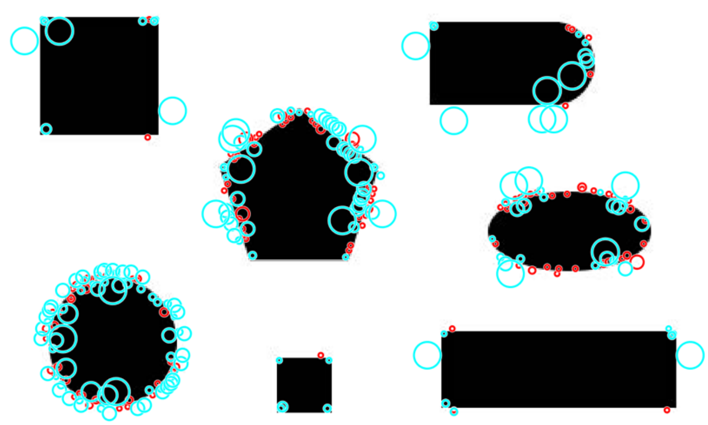




The threshold, tau, was set to 4 for the octopus image and 10 for the shapes image (see top of code.m).

Q5: Hessian constraint



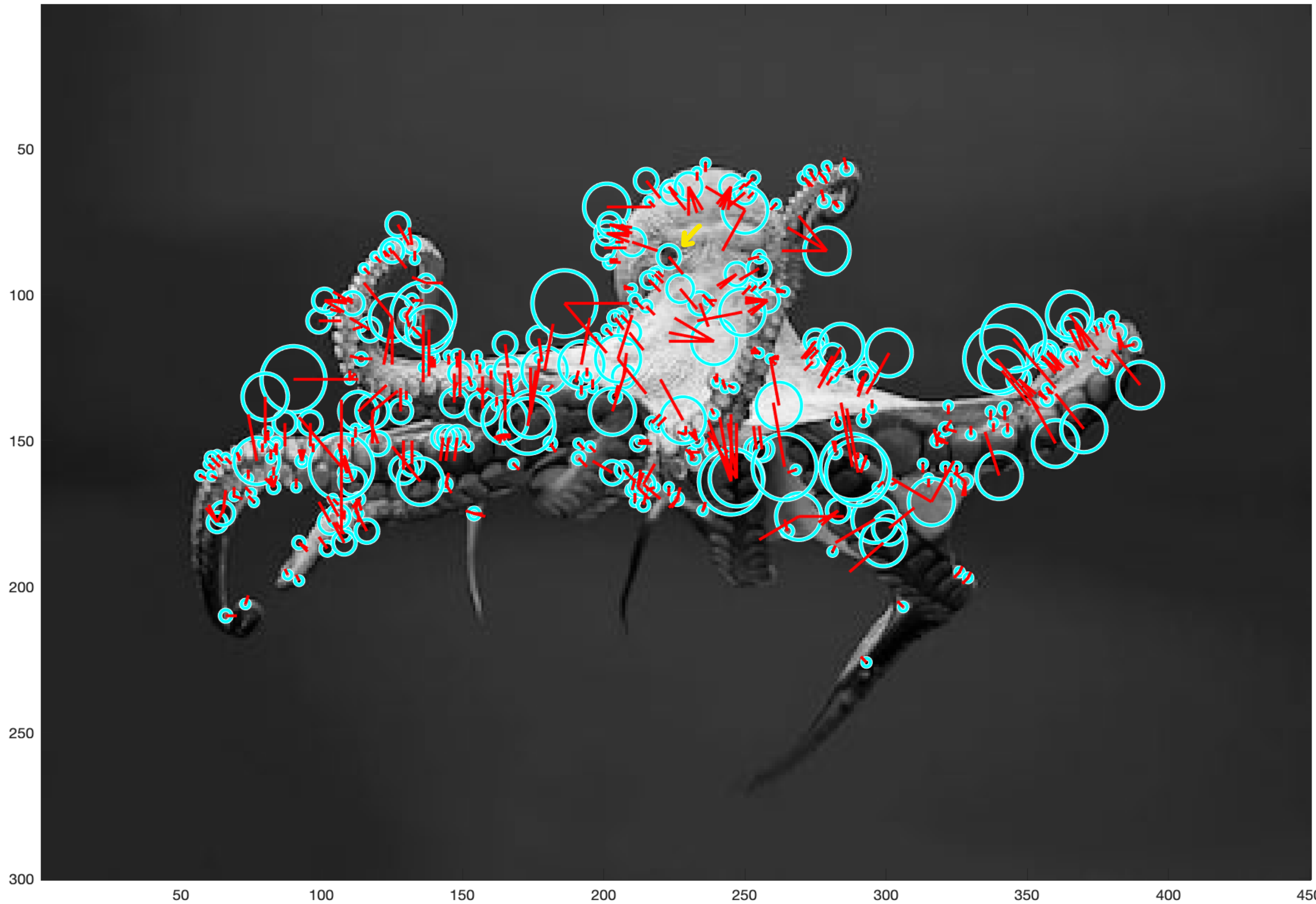


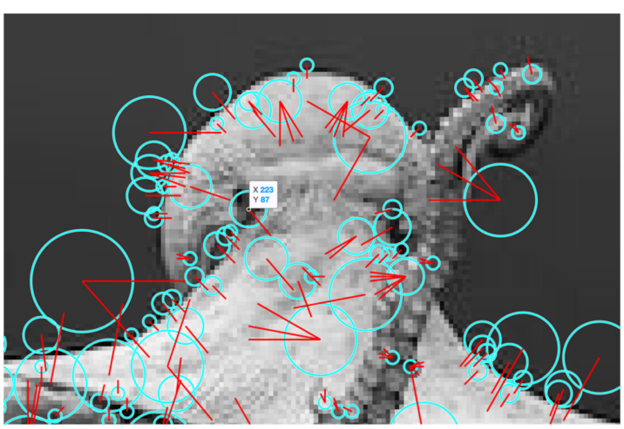
At each scale layer, the Hessian matrix was approximated as follows:

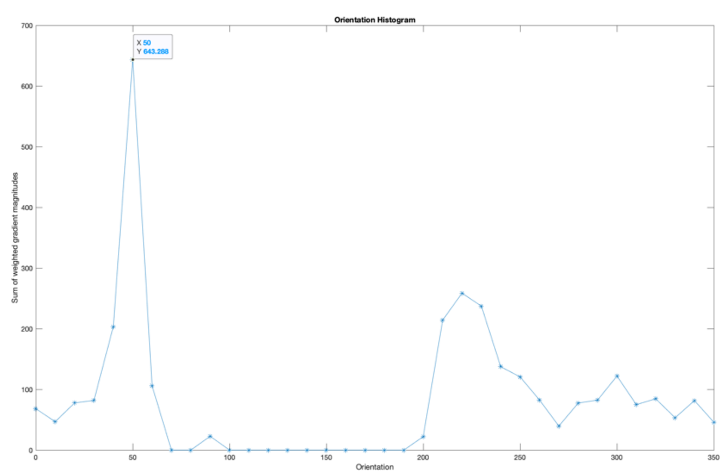
- for D_{xx}, the layer was first convolved with a **horizontal local difference filter** [1 0 -1] to compute the first partial derivative, and **again by the same filter** to compute the second partial derivative $\partial^2 f/\partial x^2$
- for D_{xy}, the layer was first convolved with a **horizontal local difference filter** [1 0 -1] to compute the first partial derivative, and **then by a vertical** local difference filter [1 0 1]' to compute the second partial derivative $\partial^2 f/\partial x \partial y$
- for D_{yy}, the layer was first convolved with a **vertical local difference filter** [1 0 -1]' to compute the first partial derivative, and **again by the same filter** to compute the second partial derivative $\partial^2 f/\partial y^2$

For comparing the ratio to the threshold, $\frac{Tr(H)^2}{Det(H)} < \frac{(r+1)^2}{r}$, r was set to 10, as in Lowe (2004).

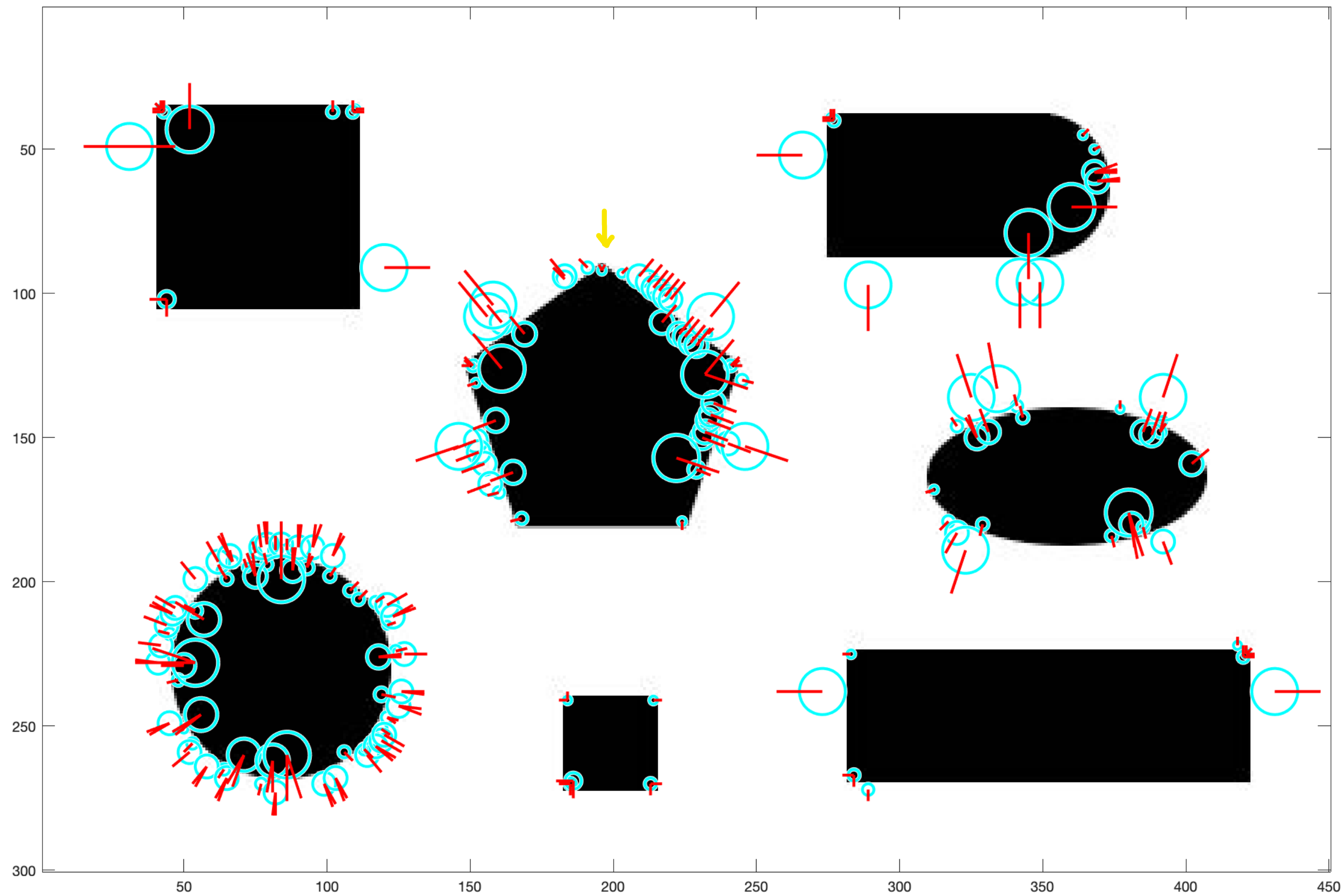
Q6: Dominant Orientation

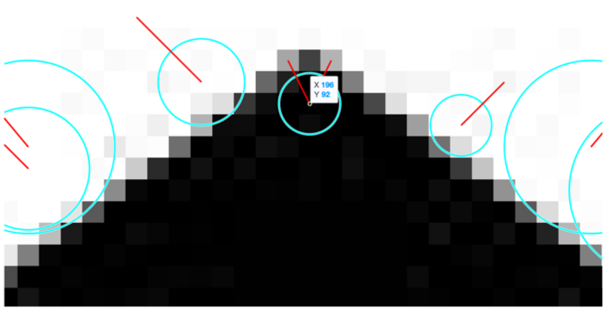


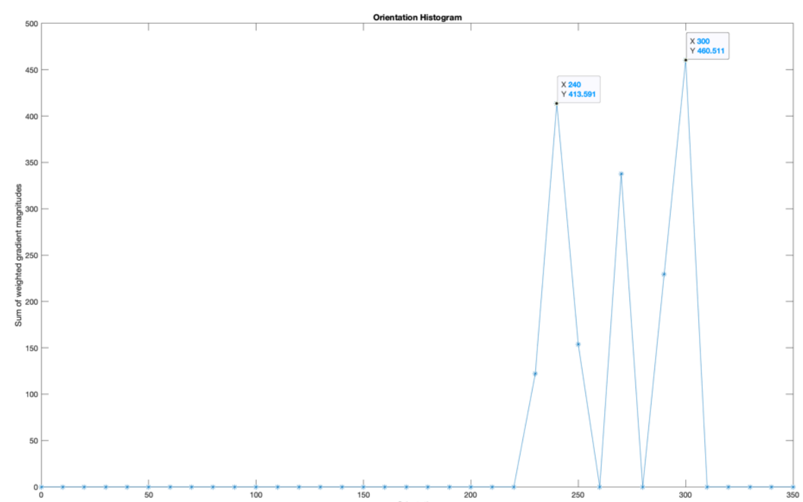




In the octopus image, the keypoint chosen was one of the creature's eyeballs at (223, 87). As seen in the orientation histogram, the point has one peak at the bin corresponding to 50 degrees, and thus one dominant orientation at 50 degrees. As seen in the image, this correctly corresponds to the orientation shown in the image, which is 50 degrees clockwise, as required.

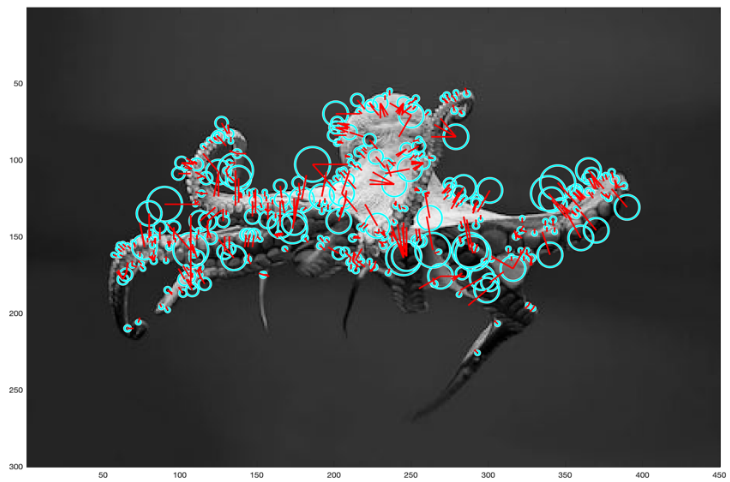




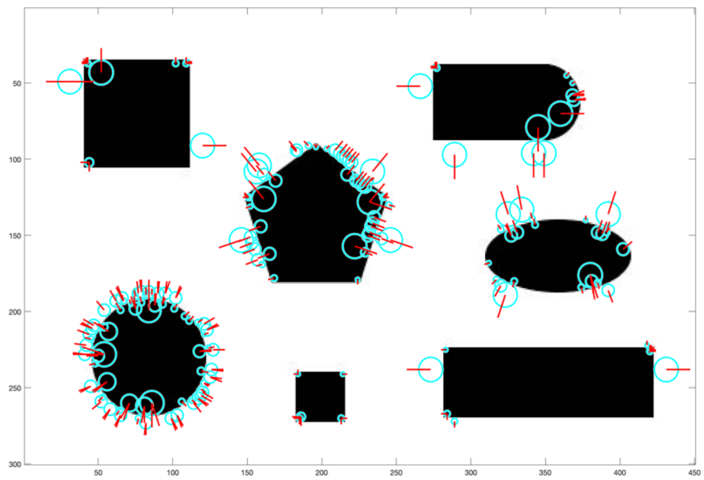


In the shapes image, the keypoint chosen was the top corner of the pentagon at (196, 92). As seen in the orientation histogram, the point has two peaks (at least 80% of the maximum peak) at the bins corresponding to 240 and 300 degrees, and thus two dominant orientations at 240 and 300 degrees. As seen in the image, this correctly corresponds to the orientations shown in the image, which are 240 and 300 degrees clockwise, as required.

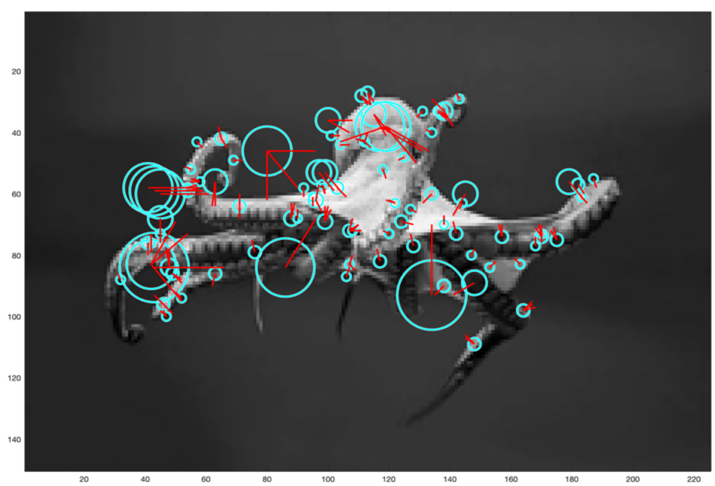
Q7: Scale Invariance (scale factor = 0.5)



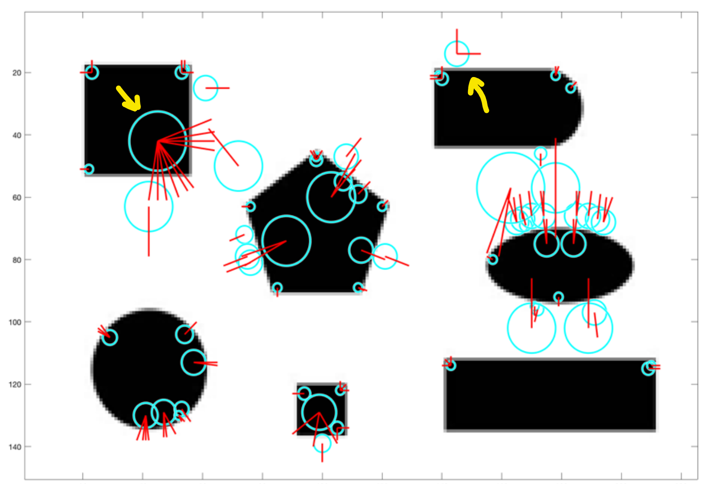
Original octopus.jpg (300 x 450)



Original shapes.jpg (300 x 450)



Re-scaled octopus.jpg (150 x 225)



Re-scaled shapes.jpg (150 x 225)

Both the octopus and shapes images were rescaled to 0.5 of their original size. The threshold for DOG keypoint magnitudes remained the same (tau = 4 for octopus.jpg, and tau = 10 for shapes.jpg), as was r = 10 for the Hessian constraint. As is clearly seen from the above figures, the keypoints are not scale-invariant (consistent across scales); in most cases, they do not correspond in the expected way with the original image keypoints. While a few keypoints are conserved, there are significantly fewer keypoints in the smaller images.

Scale: The scales of the new keypoints are much bigger on average, indicated by the larger blue circles.
Location: In the original images, the keypoints are also very close to object boundaries (edges) and other locally distinct points (corners); in the new images, the keypoints are much farther away. For example, in the re-scaled shapes.jpg, there are more keypoints well inside the shapes (black) or well outside the shapes (white).
Orientation: For the keypoints that are conserved across scale, the orientations are conserved as well. In the new images, most of the orientations point in the correct directions, although there are a few anomalies (e.g. *indicated by yellow arrows in the new shapes.jpg*: the keypoint in the square with 10 dominant orientations, or the keypoint above the rectangle+semicircle shape that points to the right).