Image and video processing: From Mars to Hollywood with a stop at the hospital.

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Week #7 *Skanda S Bharadwaj*

1. Q: Consider the general image inpainting form $\nabla L \cdot N = 0$, meaning we propagate the information L in the direction N , as we have discussed in Video 3 this week. Consider $N = (\nabla I)^{\perp}$, meaning the perpendicular ($\perp$) to the gradient of the image. What will happen if instead of propagating the Laplacian of I as in the video, we propagate the image I itself?

   - Any inpainted region will solve the basic equation $\nabla L \cdot N = 0$ for this choice.
   - We obtain an inpainted region but the transition between it and its surrounding area is not as smooth.
   - The inpainted region will be too smooth.
   - The inpainted region will be constant.

   A: Since L=I, we have that $\nabla L \cdot N = 0$ becomes $\nabla I \cdot N = 0$, and for $N = (\nabla I)^{\perp}$, we obtain $\nabla I \cdot (\nabla I)^{\perp} = 0$, which by definition holds for every image. Therefore, any inpainted region holds the equation and we don't obtain the desired result.

2. Q: Consider a region to be inpainted with N missing pixels, in an image with M pixels total. In the "smart cut-and-paste" algorithm, how many patch comparisons will need to be performed if a single pixel is inpainted per match? Consider only the order of magnitude, ignoring image boundaries for example.

   - N.
   - M/N.
   - M.
   - $N \cdot M$.

   A: For each pixel to be inpainted, we have to compare to all patches centered at each one of the M image pixels, and therefore we have a total of $N \cdot M$ searches. Some recent techniques speed-up this by either pre-processing the image or by reducing searchers to pre-specified neighborhoods.

3. Q: For a given image I, div(∇I|∇I|) is equal to (div stands for the divergence)
   - The Euclidean curvature of the image level lines.
   - The tangent to the image level lines.
   - The Gaussian curvature of the image when considered as a surface.
   - The affine curvature.

   A: This is the Euclidean curvature as we discussed in the previous week when describing basic properties of curves represented as level-lines of surfaces (functions). In video 4 this week we further discussed the use of this term as a way to smoothly continue the edges inside the region being inpainted.

4. Q: Consider that you have an image with a single circle, and a small part of it is covered and needs to be inpainted. What would you use for that?
   - A Hough transform.
   - A combination of smart cut-and-paste and PDEs.
   - A variational formulation as then one presented in Video 4.
   - A PDE as the one in Video 3.

   A: While other techniques might do a decent job, if we know the shape of the occluded object, a circle in this case, the best is to use the Hough transform to detect such object (circle) using the un-occluded regions, and once the estimation has been done, then the shape can be completed.

5. Q: Assume you have a fast moving rigid object in a video, that needs to be removed (inpainted). Which one of the following operations is expected to do a good inpainting job? If you think that more than one option is possible, pick the one that will produce the best result and/or is the simplest one.
   - Temporal median filtering: The pixels in the region to be inpainted are replaced by the median of pixels in the same (x,y) spatial location and at different frames t (median of (x,y,t) for t in some time interval with the current frame at its center).
   - Temporal Gaussian/averaging filter: The pixels in the region to be inpainted are replaced by the (weighted) average of pixels in the same (x,y) spatial location and at different frames t (median of (x,y,t) for t in some time interval with the current frame at its center).
   - A cut-and-paste technique.
   - A spatial-only inpainting via PDEs.

A: If the object is moving then pixels become un-occluded as the object passes by. If the object is moving fast, only a few frames contain the object for a given pixel location, and therefore a median will work since the majority of the pixels are un-occluded for a given time window (the size of the time window depends on the velocity of the moving object). A Gaussian will mix occluded and un-occluded pixels and then will not perform as well. A cut-and-paste technique might work but is too expensive for this simple scenario.

6. Q: How would you detect scratches in an old movie, knowing they are vertical straight lines?

   - With Mumford-Shah segmentation
   - With Wiener filtering
   - With the Hough transform

   A: The Hough transform is ideal for this since we can easily control the orientation.

7. Q: Assume the above scratches are a single pixel wide and appear in relatively uniform areas, how would you inpaint them?

   - Simple linear interpolation
   - Simple texture synthesis
   - PDE-based inpainting

   A: For such scenarios linear interpolation is the simplest thing to do and the most efficient.