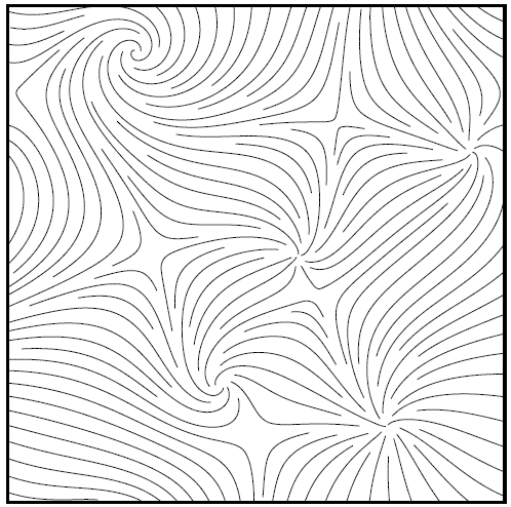
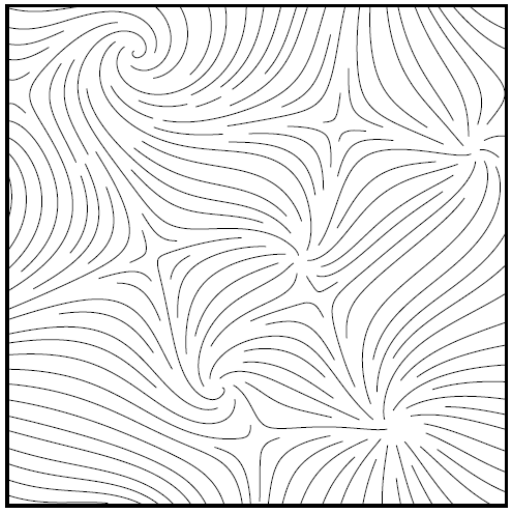
- Input
  - vector field **v**
  - seed point
- Output
  - polyline approximating the stream line

- Concepts
  - forward / backward Integration
    - integrate in **v** and **–v** to get the whole stream line
  - stop criteria
    - number of steps
    - arc length
    - domain
    - zero or low velocity
  - arc length parameterized output
    - integration in the direction field $\mathbf{v}_d = \frac{\mathbf{v}}{\|\mathbf{v}\|}$

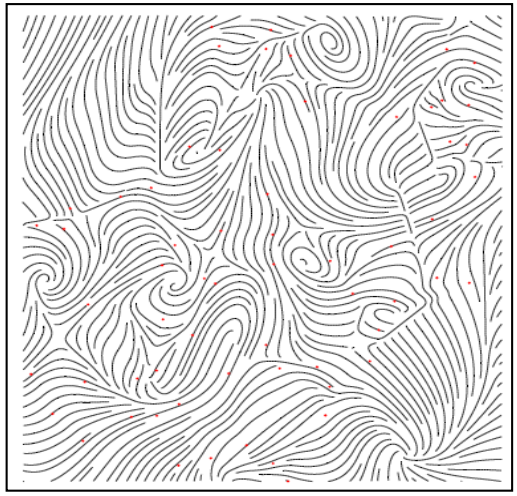
- **Seeding of integral lines:**
- which stream/path/streak/time lines to visualize?
- too few: important details get lost
- too many: overload, visual clutter
- simple approaches:
  - start on regular grid points
  - start randomly



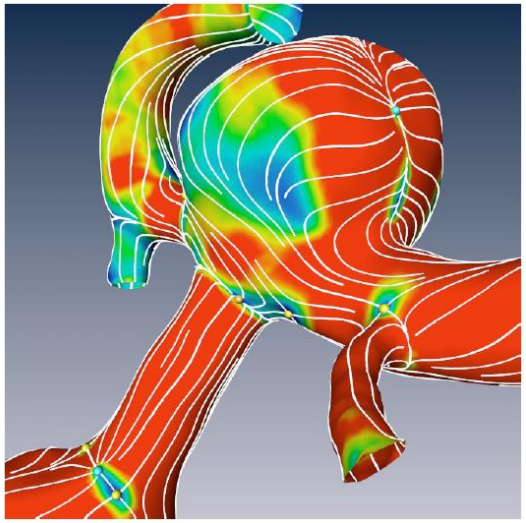
Turk and Banks, 1996



Jobard et al., 1997

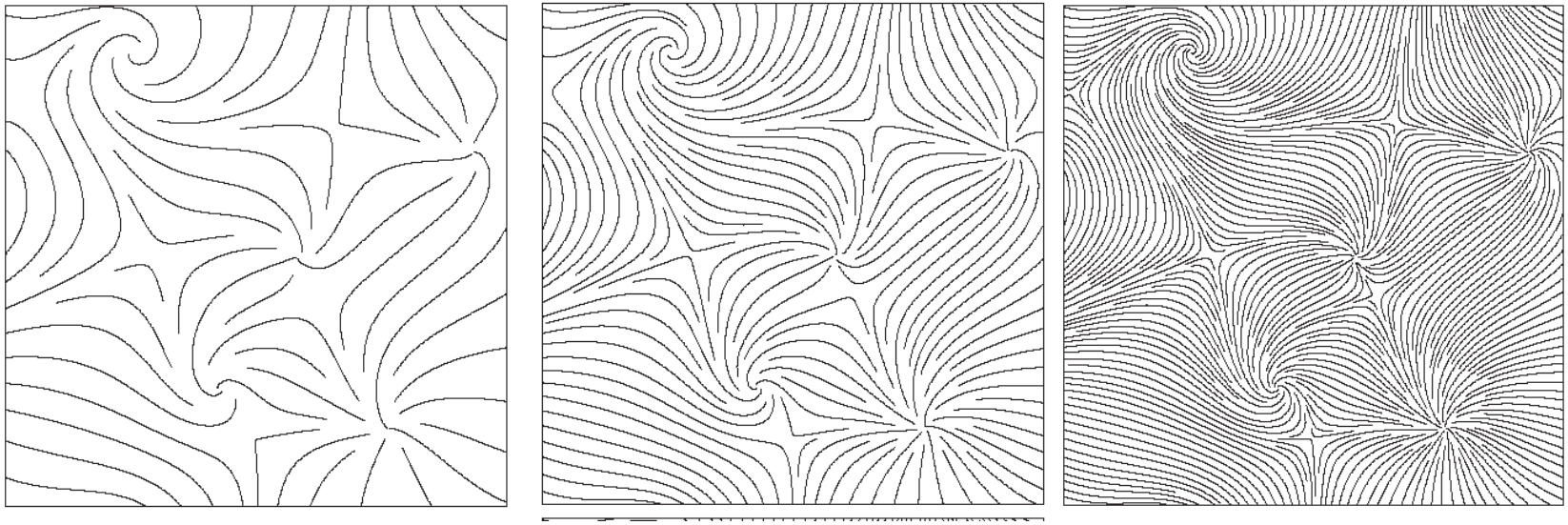


Mebarki et al., 2005



Rosanwo et al., 2009

- **Stream line seeding:**
  - 2D: evenly spaced stream lines
  - **Turk/Banks 96:**
    - start with streamlets (very short stream lines)
    - apply a series of energy-decreasing elementary operations: combine, delete, create, lenghten, shorten streamlets
    - energy: difference between low-pass filtered version of current placements and uniform grey image



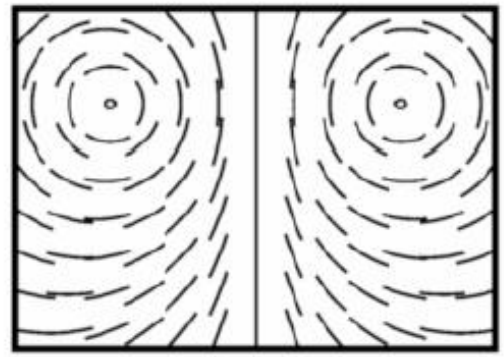


Figure 2: (a) Short streamlines with centers placed on a regular grid (top); (b) filtered version of same (bottom).

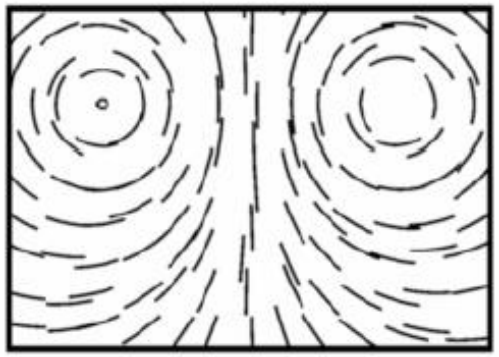


Figure 3: (a) Short streamlines with centers placed on a jittered grid (top); (b) filtered version showing bright and dark regions (bottom).

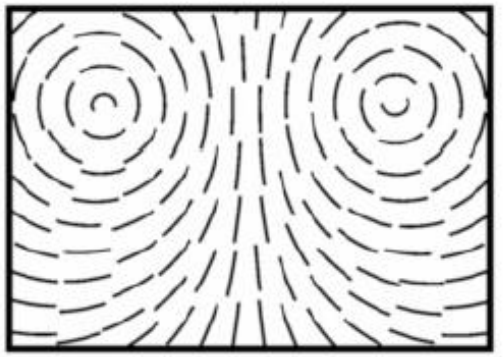
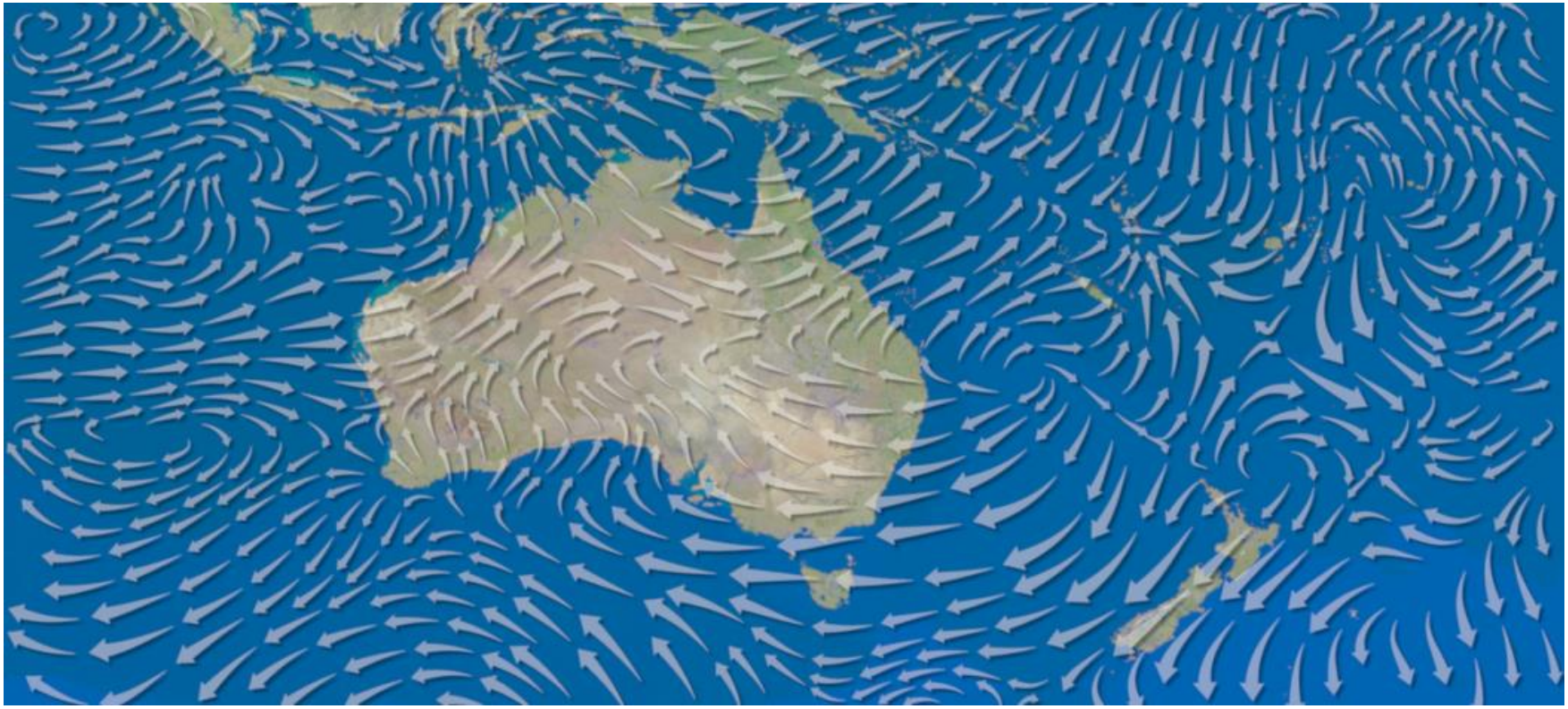


Figure 4: (a) Short streamlines placed by optimization (top); (b) filtered version showing fairly even gray value (bottom).



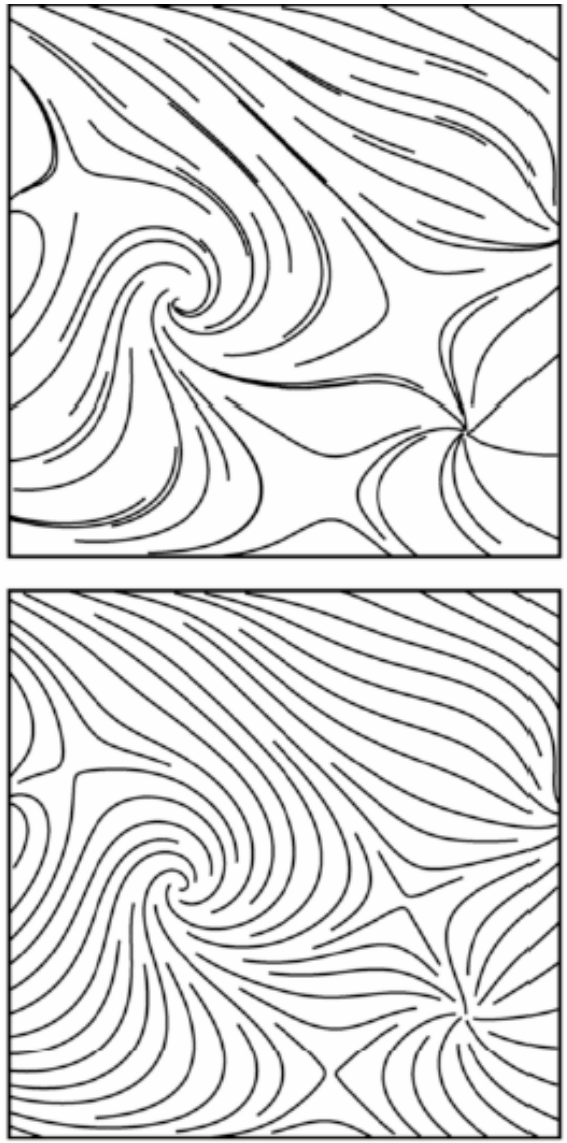
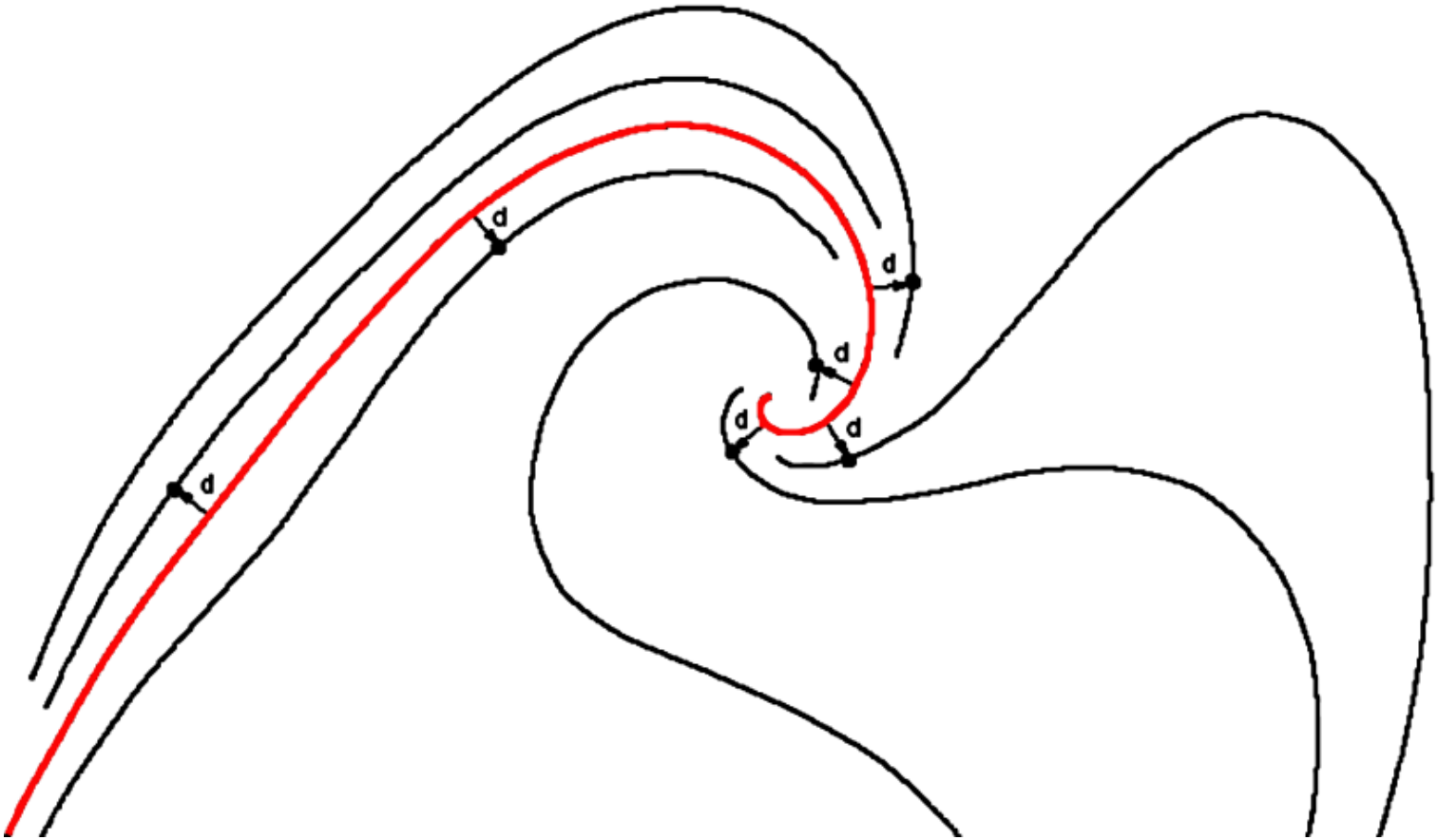


Figure 5: (a) Long streamlines with centers regularly placed on a grid (top); (b) Streamlines placed by density-based optimization (bottom). This data is a randomly generated vector field.

- **Stream line seeding:**
  - 2D: evenly spaced stream lines
  - **Jobart/Lefer 97:**
    - greedy placement of new stream lines in the neighborhood of already present stream lines
    - 2 steering parameters d_{sep}, d_{test} with $d_{test} < d_{sep}$
    - Start integration of an arbitrary stream line in forward and backward direction until it
      - Leaves the domain
      - Ends in a critical point
      - Comes closer than d_{test} to another drawn stream line
    - Next stream line: starts in a point with distance d_{sep} to first stream line
    - Ends when no further stream lines are possible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