Progress in Dynamic Texture Showcase

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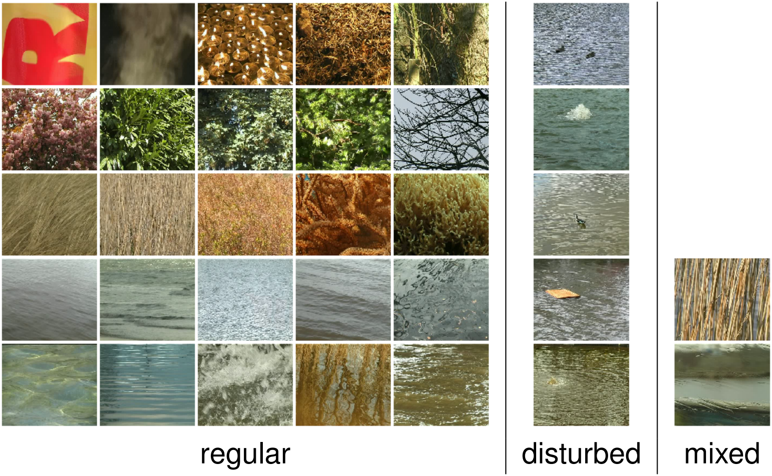
Outline

Categories of visual motion patterns

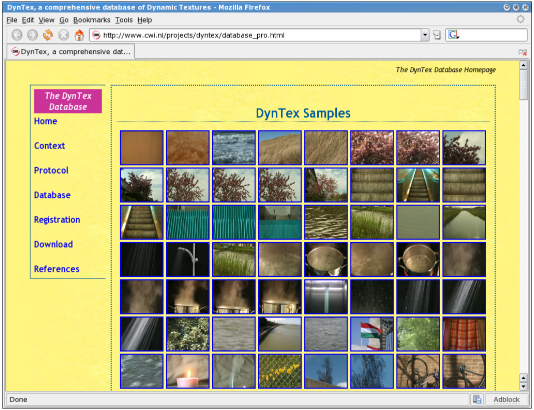
- Activities
  - periodic in time, localised in space
  - $\Rightarrow$ walking, digging
- Motion events
  - no temporal or spatial periodicity
  - $\Rightarrow$ opening a door, jump
- Temporal textures
  - statistical regularity, indeterminate spatial and temporal extent
  - $\Rightarrow$ fire, smoke

Examples of dynamic textures



⇒ show sample videos

DynTex database by NoE MUSCLE



http://www.cwi.nl/projects/dyntex/

- 656 digital videos
- PAL 720 x 576, 25 fps
- Length $\geq$ 250 frames
- Closeups and contexts
- Static/moving camera
- Indoor and outdoor natural scenes
- Annotated, categorised (work in progress)
- Available on the Web ($\gtrsim$ 50 registered users)

(In collaboration with R. Péteri, M. Huiskes, and CWI)

Non-regular optical flow for dynamic texture

- Work in progress with Tel-Aviv Unversity (TAU)
  - Tomer Amiaz
  - Nahum Kiryati
- Dynamic textures have strong intrinsic dynamics
  - motion cannot be compensated by shift/rotation
  - intensity constancy assumption not valid
  - standard (regular) optical flow not precise
- Use intensity conservation assumption instead
  - non-regular optical flow with divergence term
  - intensity may diffuse
- Dynamic texture detection
  - segmenting flow into regular and non-regular part
  - indicator function in level-set implementation

Brightness conservation assumption

- Non-regular optical flow (compared to Horn-Schunck)

$$\begin{array}{rrcl} \text{Brightness constancy:} & I(x+u, y+v, t+1) & = & I(x, y, t) \\ \text{Optical flow constraint:} & I_t + uI_x + vI_y & = & 0 \\ \hline \text{Brightness conservation:} & I(x+u, y+v, t+1) & = & I(x, y, t)(1 - u_x - v_y) \\ \text{Continuity equation:} & I_t + uI_x + vI_y & = & -I \cdot (u_x + v_y) \end{array}$$

- Brightness of an image point (in one frame) can propagate to its neighborhood (in the next frame)
- Captures more information than a regular flow
- Encodes the warp residual of a regular flow
- Applicable to strong dynamic textures (generic feature)

Optical flow equations

- Horn-Schunck
  - brightness constancy ($\boldsymbol{v} = (u, v)$: velocity vector)

$$\partial_t I + \boldsymbol{v} \cdot \nabla I = 0$$

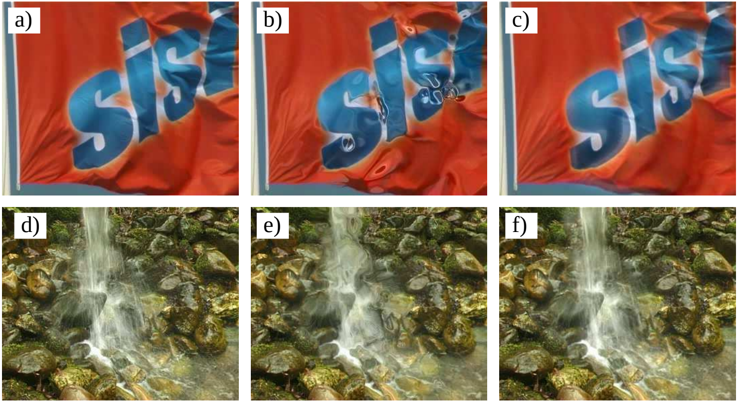
  - Lagrangian

$$L_{HS}(u, v) = (I_t + uI_x + vI_y)^2 + \alpha(u_x^2 + u_y^2 + v_x^2 + v_y^2)$$

  - minimise $F_{HS}(u, v) = \int_I L_{HS}(u, v)\,\mathrm{d}x\mathrm{d}y$
- Brightness conservation

$$\partial_t I + \boldsymbol{v} \cdot \nabla I + I\,\mathrm{div}\,\boldsymbol{v} = 0$$

  - Lagrangian more complicated, but essentially similar



(a,d): frame 1 of dynamic texture; (b,e): frame 2 warped back by regular flow; (c,f): same by non-regular flow

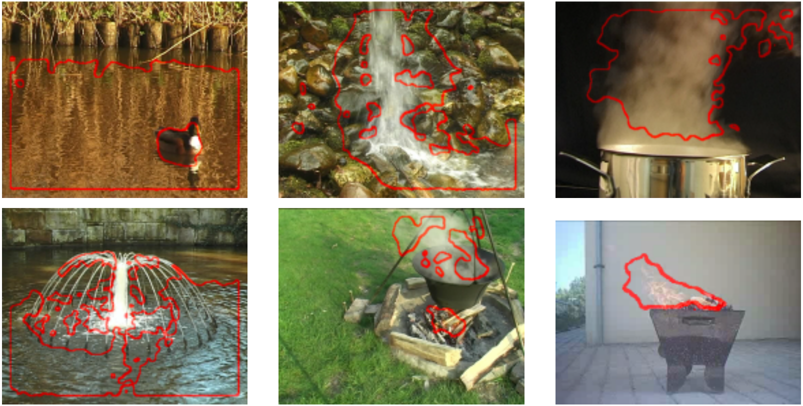
Level set segmentation

- Segmentation as a variational problem

$$
\begin{aligned}
& L_{DTS}(u, v, \tilde{u}, \tilde{v}, \phi) = \\
& \qquad (I_t + uI_x + vI_y)^2 \, H(\phi) + (I_t + \tilde{u} I_x + \tilde{v} I_y + I\tilde{u}_x + I\tilde{v}_y)^2 \, H(-\phi) \\
& \qquad + \alpha(u_x^2 + u_y^2 + v_x^2 + v_y^2) + \tilde{\alpha}(\tilde{u}_x^2 + \tilde{u}_y^2 + \tilde{v}_x^2 + \tilde{v}_y^2) + \tilde{\beta}(\tilde{u}^2 + \tilde{v}^2) \\
& \qquad + \nu |\nabla H(\phi)| \\
& F_{DTS}(u, v, \tilde{u}, \tilde{v}, \phi) = \int_I L_{DTS}(u, v, \tilde{u}, \tilde{v}, \phi) \, \mathrm{d}x\mathrm{d}y
\end{aligned}
$$

- Brightness constancy on static and weak dynamic regions
- Brightness conservation on strong dynamic regions
- Smooth boundary of segmented regions
- Solved (Euler-Lagrange eqs., discretisation based on central derivatives, iterative solver, . . .)

Results



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Versions: Making it faster

- Full algorithm
  - precise segmentation
  - no thresholding needed (decision by indicator function)
  - currently, slow (15–20 sec/frame)
  - ⇒ make faster using graph cuts
- Fast simplified version
  - less precise segmentation
  - threshold learned, then adjusted adaptively
  - close to real-time (5–10 fps)
- Real-time simplified version
  - less precise segmentation, sometimes errs
  - threshold adjusted adaptively
  - real-time (20–25 fps)

Summary

- Collaborative work of SZTAKI and TAU
- Showcase with Bilkent
- Generic method for detecting dynamic textures
  - processes of various physical origin
- More than just detection/segmentation
  - calculates optical flow useful for recognition
- Plans
  - speed up full algorithm (graph cuts)
  - improve real-time version: automatic threshold, adaptivity
  - distinguish between DTs and other fast motion
  - integrate with periodicity detection and DT recognition