IDENTIFYING BEHAVIORS IN CROWDED SCENES THROUGH STABILITY ANALYSIS FOR DYNAMICAL SYSTEMS

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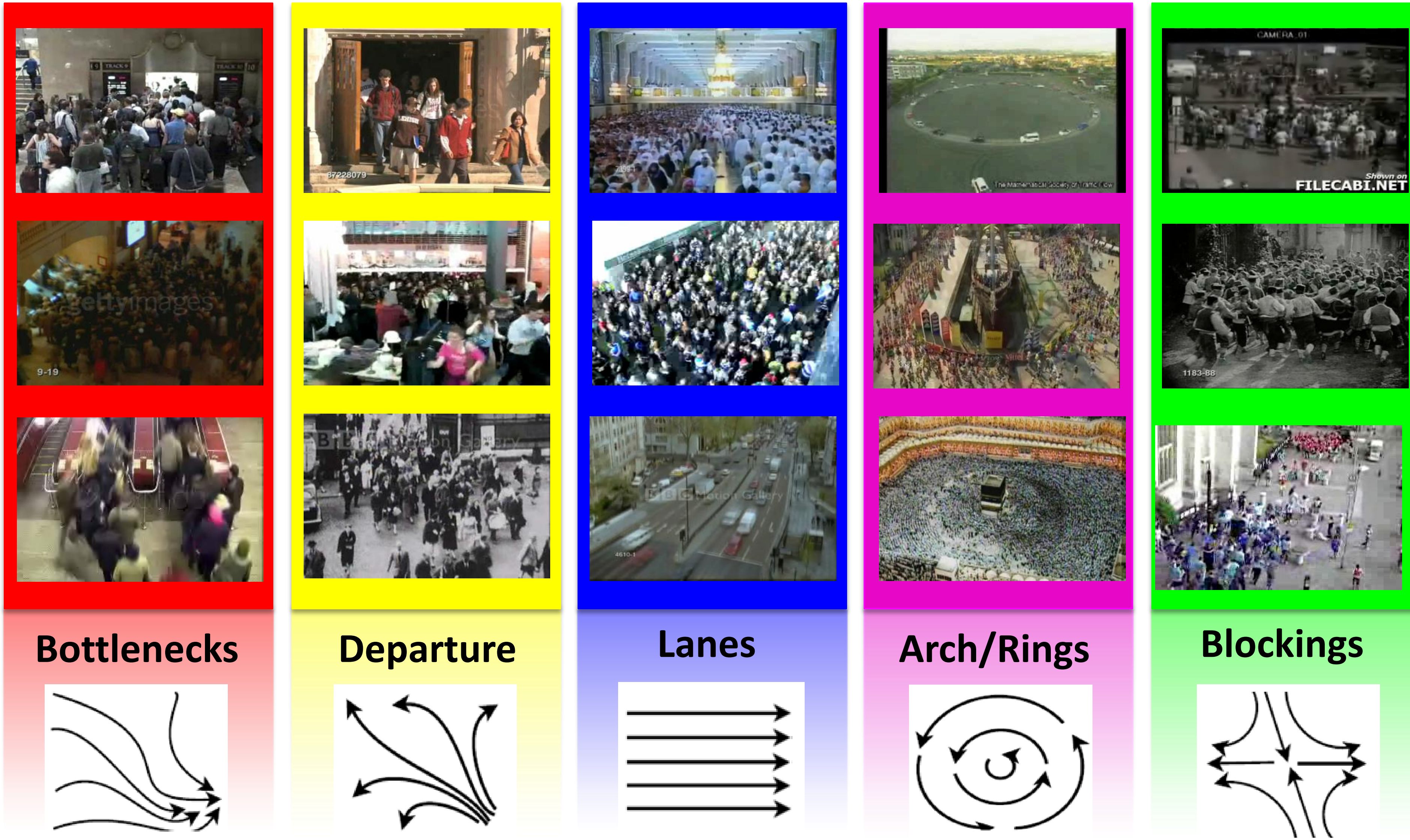
Outline

- Behaviors to be Identified
- Theoretical Concepts
  - Lagrangian Particle Dynamics, Numerical Integration
  - Linearization of Dynamical Systems, Jacobian Matrix
- Proposed Framework
- Experimental Results

Behaviors in Crowded Scenes

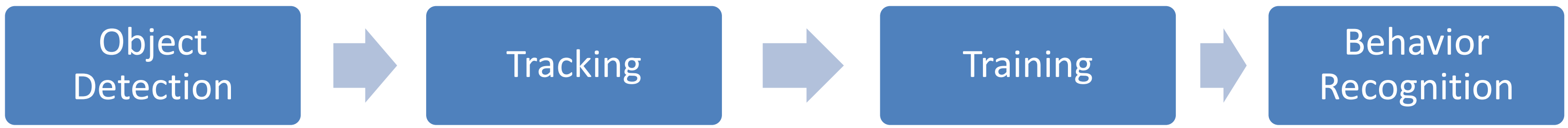


Identifying Behaviors in Crowded Scenes

Challenges :

- Various real-world conditions
- High-densities of moving objects
- Difficult to analyze behaviors of individuals

Conventional Approaches for Behavior Analysis



- Fail for high density of objects
- Computationally expensive
- Require training, hence the manual isolation of behaviors

Theory Behind Our Method (Lagrangian Particle Dynamics)

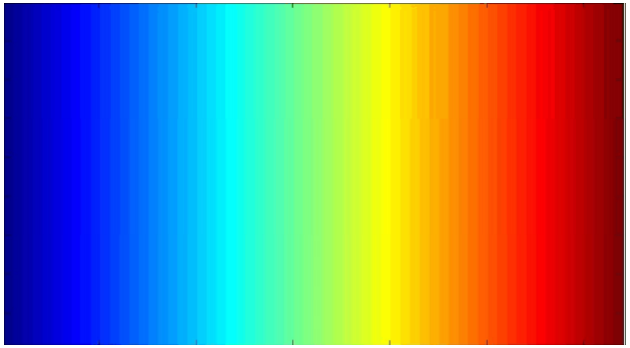
Sequence

Optical Flow $F(\mathbf{y}(t))$

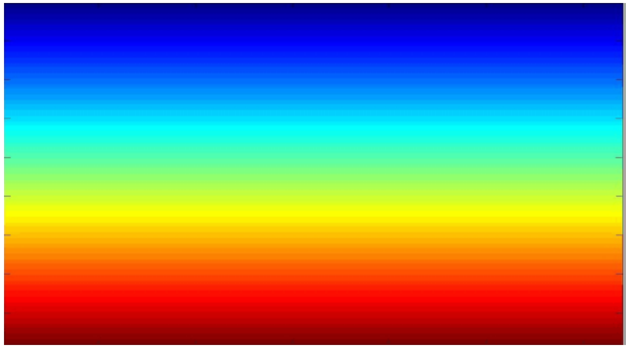
using numerical integration,

Euler's Method $\mathbf{y}(t+1) = \mathbf{y}(t) + F(\mathbf{y}(t))$

Particle Trajectories



Φ_x (x-flowmap)



Φ_y (y-flowmap)

positions of particles

Theory Behind Our Method (Linearization of a Dynamical System)

$$\frac{dx}{dt} = \mathrm{f(x,y)} \qquad \frac{dy}{dt} = \mathrm{g(x,y)}$$ particle velocities (1)

$$f(x^*, y^*) = 0 \qquad g(x^*, y^*) = 0$$ fixed points (2)

By Taylor's theorem $$f(x,y) \approx \mathrm{f}(x^*, y^*) + f_x(x^*, y^*)(x - x^*) + f_y(x^*, y^*)(y - y^*)$$ (3)

where f_x and f_y are partial derivatives

$$\frac{dx}{dt} = \mathrm{f(x,y)} = \mathrm{f}(x^*, y^*) + f_x(x^*, y^*)(x - x^*) + f_y(x^*, y^*)(y - y^*)$$ (4)

$$u = (x - x^*) \qquad v = (y - y^*)$$ new coordinates (5)

$$\frac{du}{dt} = \frac{dx}{dt} \qquad \frac{dv}{dt} = \frac{dy}{dt}$$ (6)

$$\frac{du}{dt} = f_x(x^*, y^*)u + f_y(x^*, y^*)v \qquad \frac{dv}{dt} = g_x(x^*, y^*)u + g(x^*, y^*)v$$ (7)

$$\vec{\boldsymbol{u}} = \begin{bmatrix} u \\ v \end{bmatrix} \qquad \frac{d\vec{\boldsymbol{u}}}{dt} = \mathrm{J}\,\vec{\boldsymbol{u}}$$ (8)

$$J = \begin{bmatrix} f_x(x^*, y^*) & f_y(x^*, y^*) \\ g_x(x^*, y^*) & g_y(x^*, y^*) \end{bmatrix}$$ Jacobian matrix

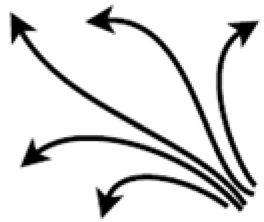
Eigenvalues of Jacobian Matrix

Jacobian matrix $J = \begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix}$ → Eigenvalues λ_1 , λ_2

Sink

$\lambda_1<0\ \lambda_2<0$

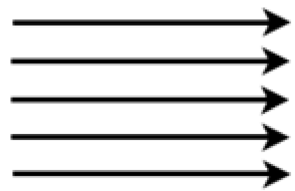
Bottleneck



Source

$\lambda_1>0\ \lambda_2>0$

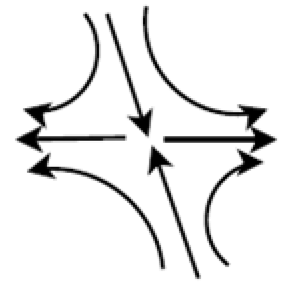
Departure (Fountainhead)



Line of fixed points

$\lambda_1=0$ *or* $\lambda_2=0$

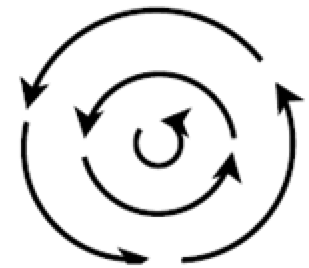
Lane



Saddle

$\lambda_1<0<\lambda_2$

Blocking

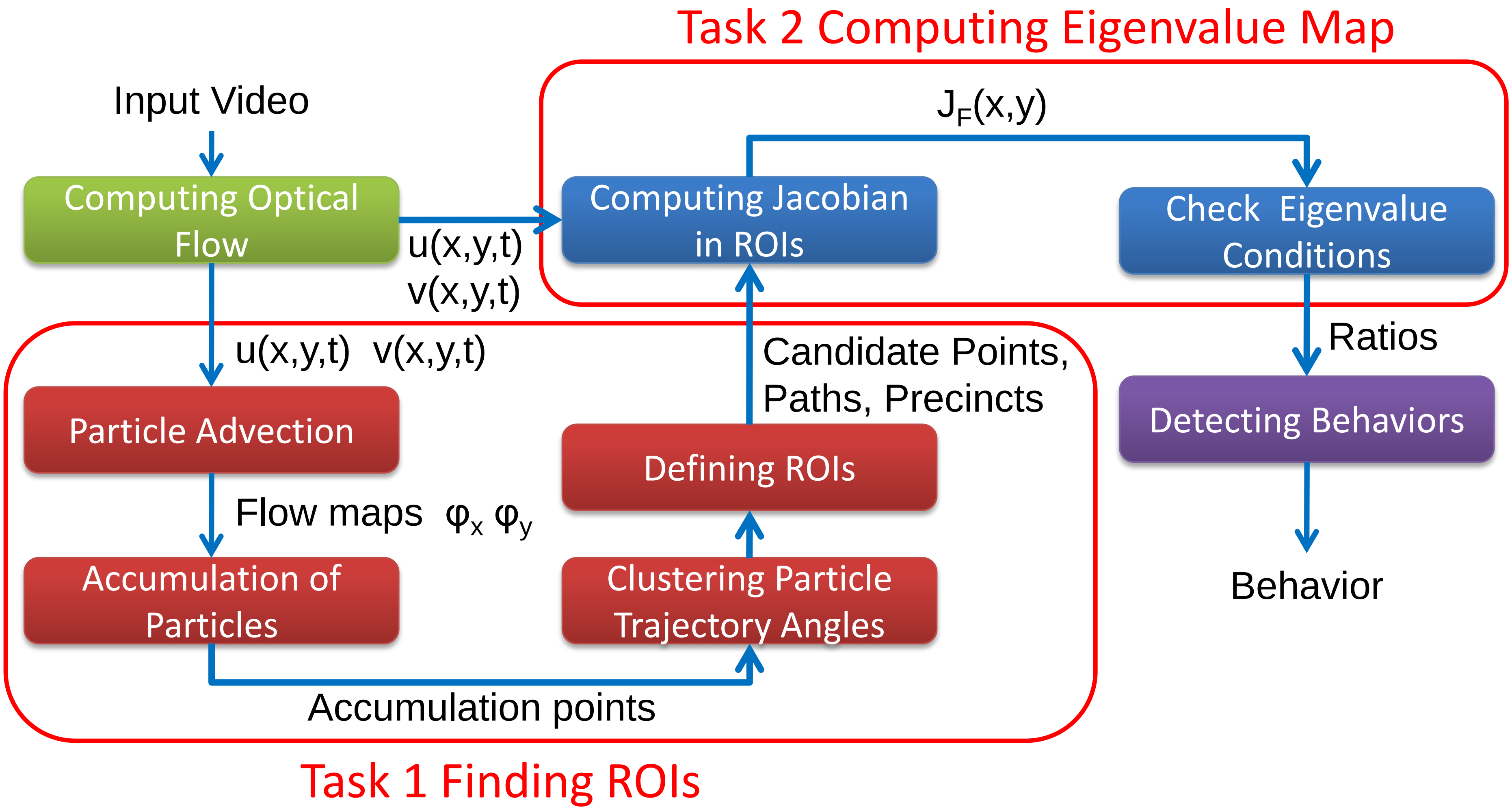


Center

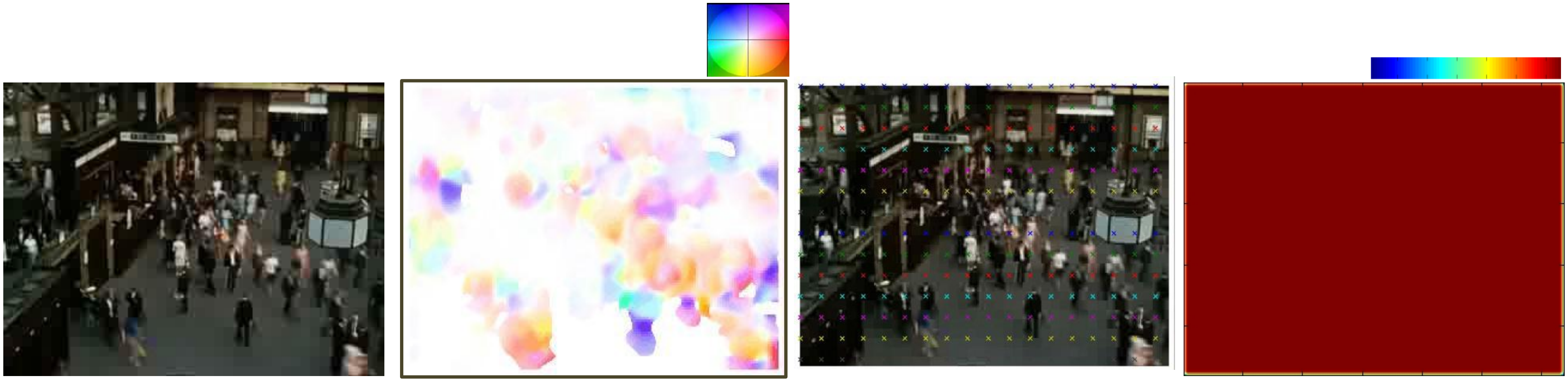
λ_1 *and* λ_2 *complex conj.*

Arch/Ring

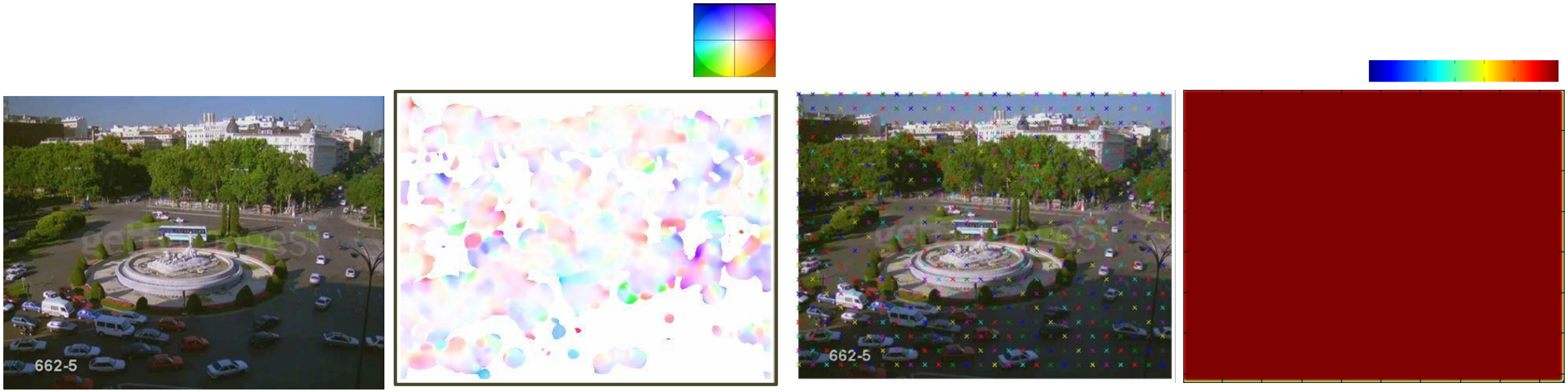
Proposed Framework



Task 1 – Finding ROIs

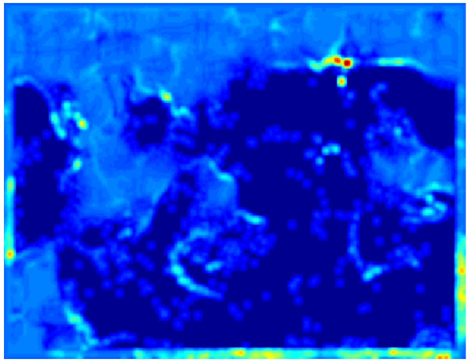


Sequence | Optical Flow | Particle Trajectories | Density Map



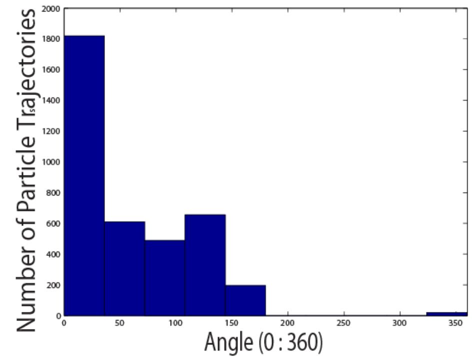
Sequence | Optical Flow | Particle Trajectories | Density Map

Task 1 – Finding ROIs

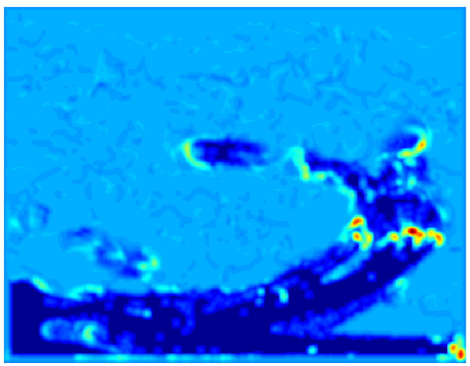

Density Map


Accumulation Points


Particle Trajectories



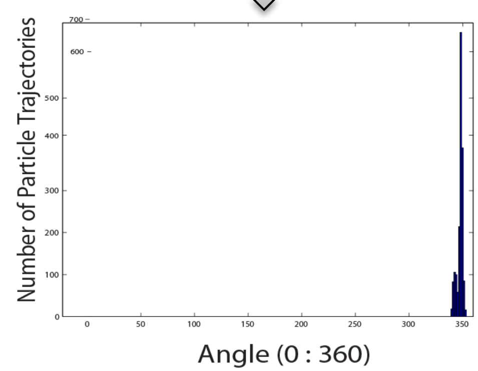
Angles of Trajectories


Density Map

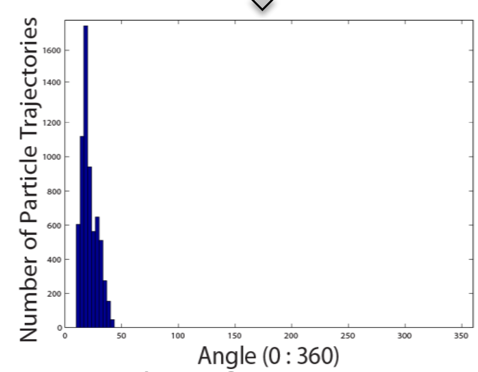
Accumulation Points

Particle Trajectories

Particle Trajectories



Angles of Trajectories

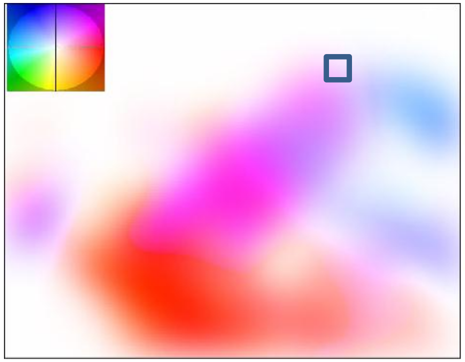


Angles of Trajectories

Various directions → Candidate point for Bottleneck

One direction → Candidate paths for Lanes or Arches/Rings

Task 2 – Computing Eigenvalue Map



Average Optical Flow

Eigenvalue Map

Around Candidate Point

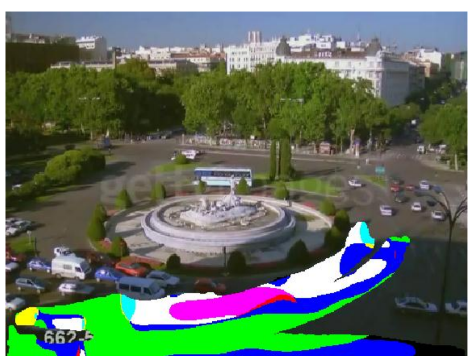
$$J = \begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix} \rightarrow \lambda_1, \lambda_2$$

$\lambda_{1,2}$ real
- $\lambda_1<0 \;\; \lambda_2<0$
- $\lambda_1>0 \;\; \lambda_2>0$
- $\lambda_1=0$ or $\lambda_2=0$
- $\lambda_1<0<\lambda_2$

$\lambda_{1,2}$ complex
- $\lambda_{1,2}=\alpha\pm j\beta,\ \alpha<0$
- $\lambda_{1,2}=\alpha\pm j\beta,\ \alpha>0$
- $\lambda_{1,2}=\pm j\beta$

No motion

Average Optical Flow



Eigenvalue Map

Around Candidate Path

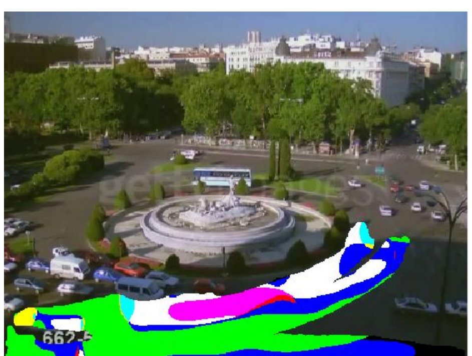
Ratios & Identified Behaviors

Eigenvalue Map

Around Candidate Point

Bottleneck

Identified Behavior	Ratio Condition
Bottleneck	Red / Total > Thr
Lane	Blue / Total > Thr
Arch/Ring	(White+Cyan+Magenta) / Total > Thr



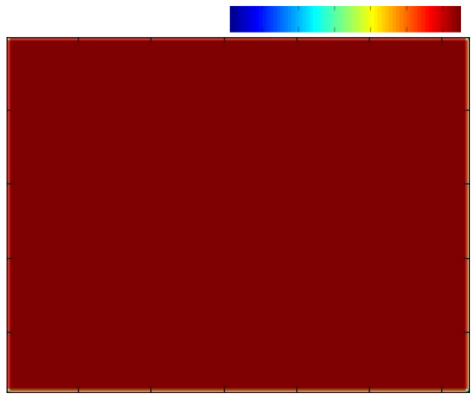
Eigenvalue Map

Around Candidate Path

Lane and Arch

Detecting Departure

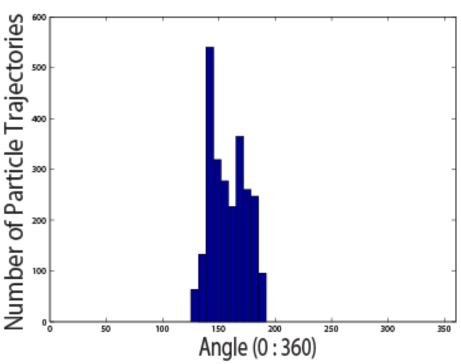
Particle Trajectories



Density Map

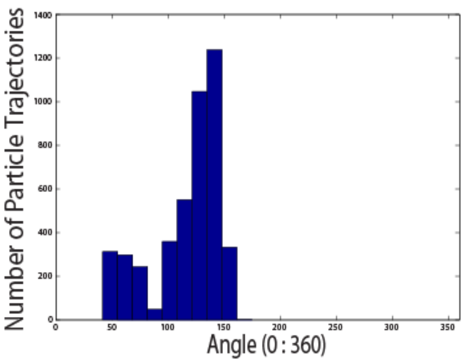
Accumulation Points

Particle Trajectories



Angles of Trajectories

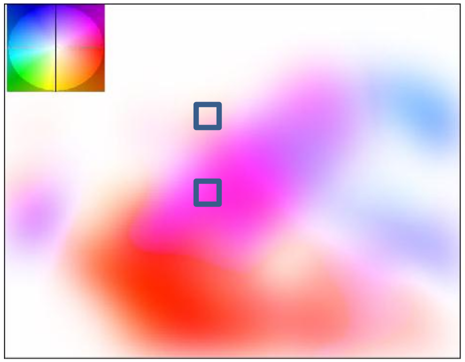
Particle Trajectories



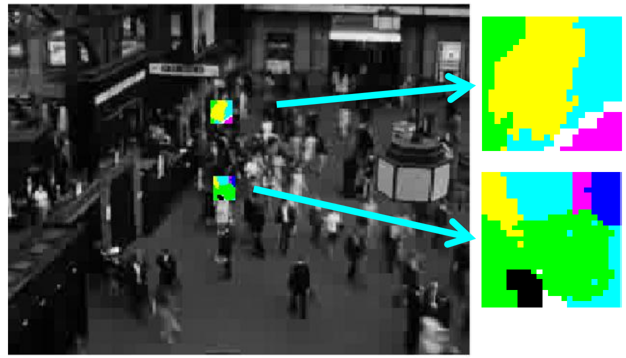
Angles of Trajectories

Various directions → Candidate points for Departure

Detecting Departure



Average Optical Flow



Eigenvalue Map

Around Candidate Point

Departure

- $\lambda_1<0\ \ \lambda_2<0$
- $\lambda_1>0\ \ \lambda_2>0$
- $\lambda_1=0$ or $\lambda_2=0$
- $\lambda_1<0<\lambda_2$
- $\lambda_{1,2}=\alpha\pm j\beta,\ \alpha<0$
- $\lambda_{1,2}=\alpha\pm j\beta,\ \alpha>0$
- $\lambda_{1,2}=\pm j\beta$
- *No motion*

Identified Behavior	Ratio Condition
Departure	Yellow / Total > Thr

Experiments on Real Videos

- YouTube, Getty-Images, BBC Motion Gallery, Though Equity
- 60 videos including Crowd and Traffic Scenes
- Ground Truth

  -Positions of bottlenecks/departures/blockings

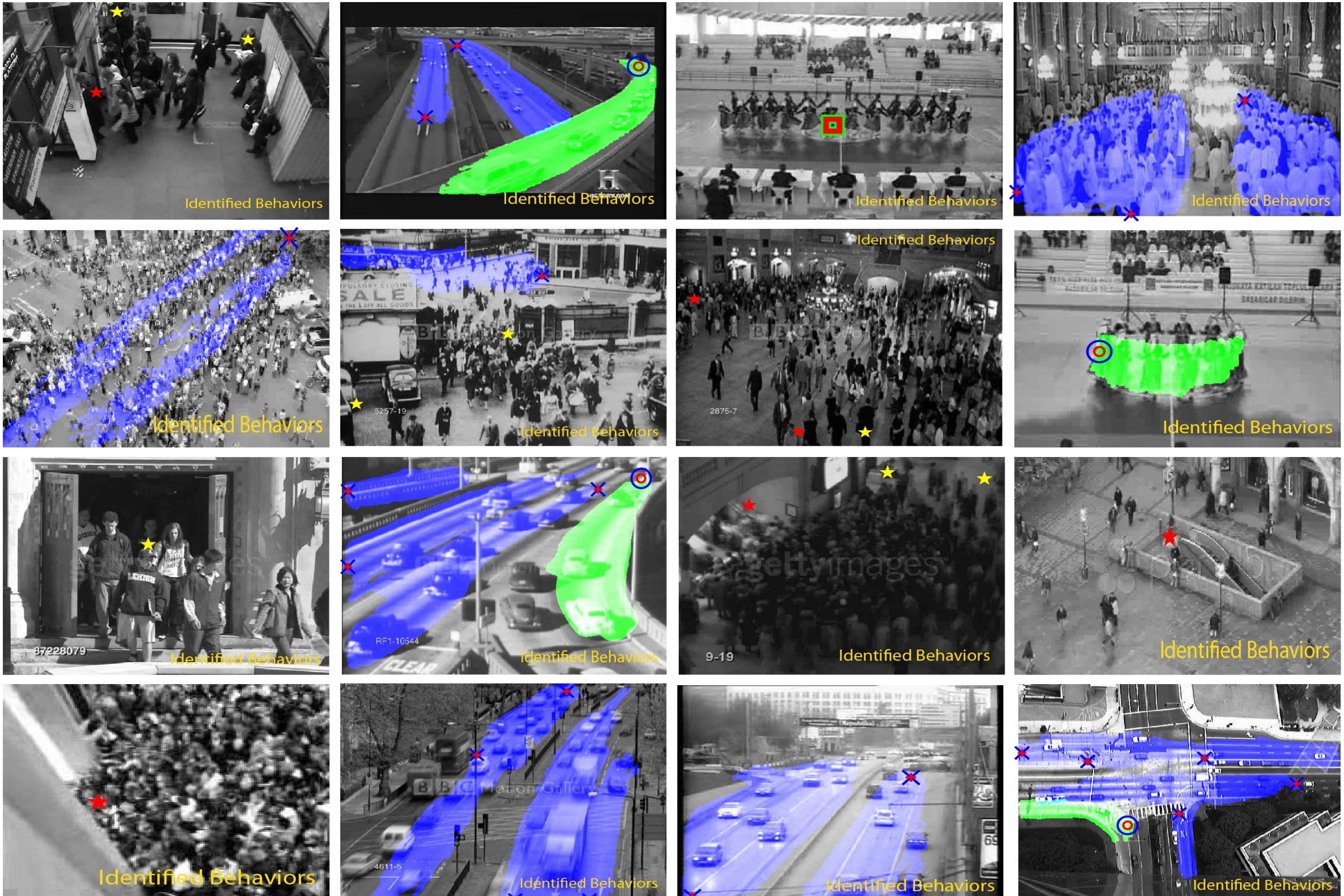
  -Paths of lanes/arches/rings

- Evaluation Criteria

  -Distance test for bottlenecks/departures/blockings

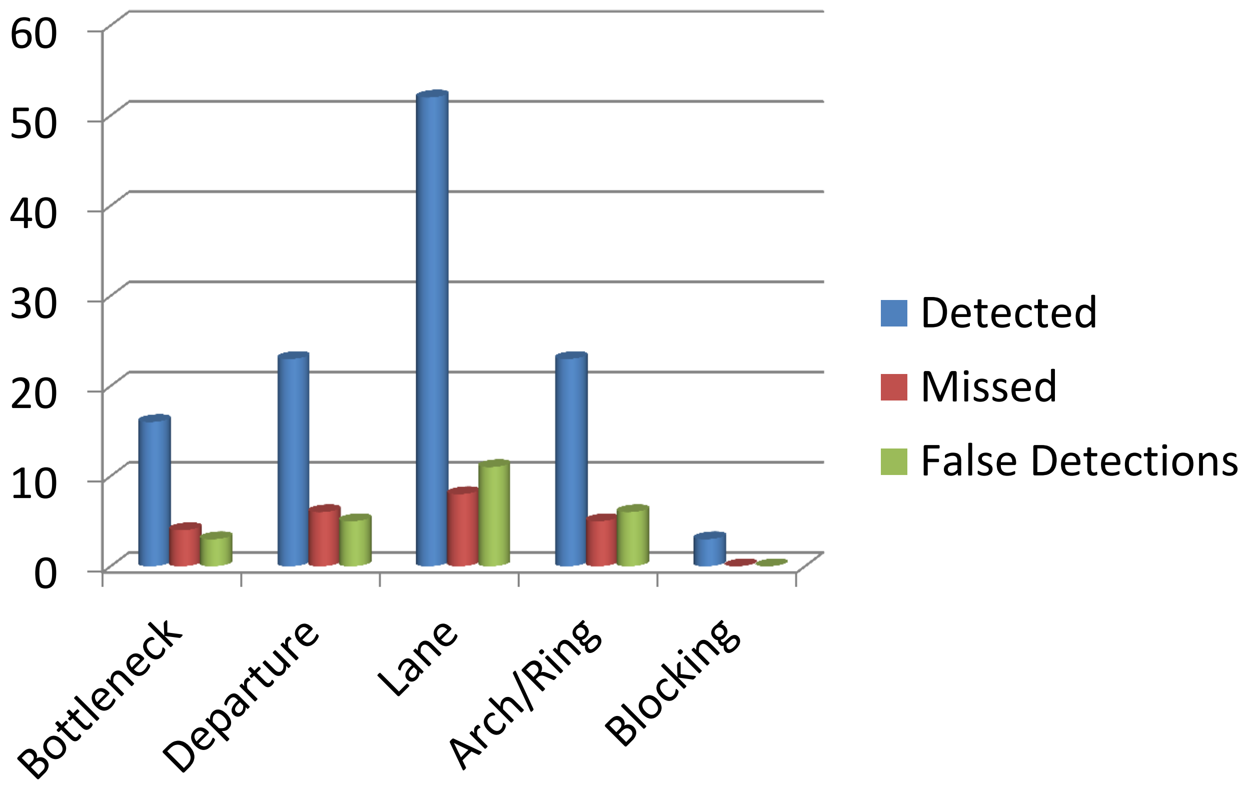
  -Path overlap ratio test for lanes/arches/ring

Identified Behaviors on Real Videos



★ : Bottleneck ★ : Fountainhead ◎ : Arch/Ring ✕ : Lane ▣ : Blocking

Quantitative Results (I)



Advantages

- Integrates of low-level local motion features and high-level information of the scene
- Performs well in various types of crowded scenes
- No training, or detection and tracking
- No isolation of activities
- Fast and robust to occlusions
- Multiple behavior identification

Thank You