MATLAB and its application in Engineering

Assoc. Prof. Kirin Shi

施圣贤

上海交通大学

机械与动力工程学院

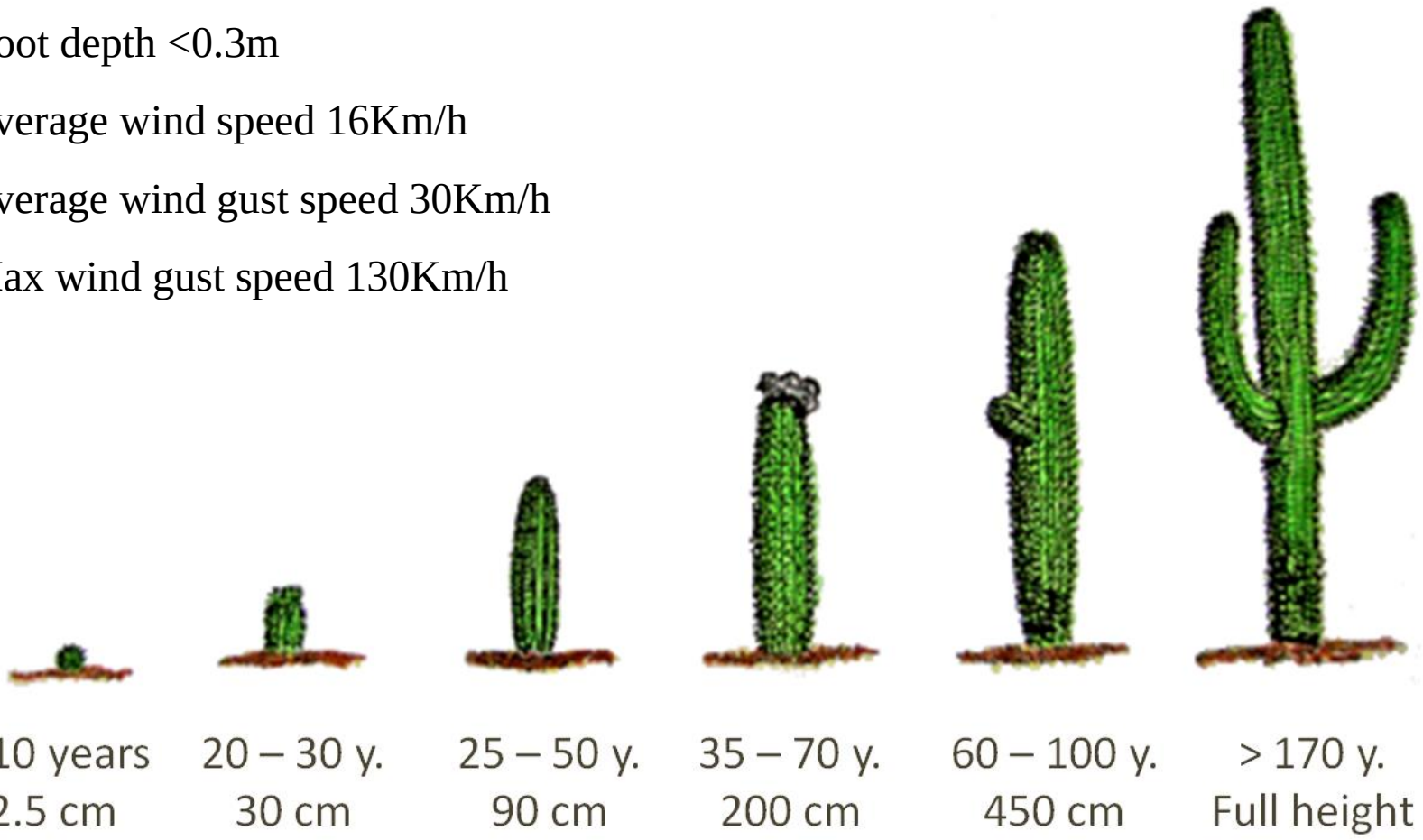
Applications in Fluid Research

- Image Processing in Particle Image Velocimetry
- Ray Tracing in Light Field Imaging
- Data Processing in Pressure Sensitive Paint

Image Processing in PIV

Saguaro (tree-sized cactus 仙人掌)

- Over 20m height
- Root depth <0.3m
- Average wind speed 16Km/h
- Average wind gust speed 30Km/h
- Max wind gust speed 130Km/h



Flow measurement

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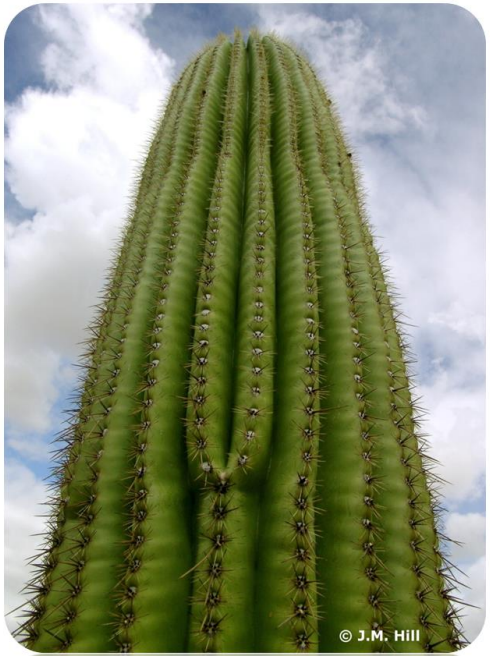

Why measure flow velocity

The Tacoma Narrows Bridge disaster (state of Washington, USA)

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Flow measurement

Why a concrete-steel build bridge being destroyed by mild wind?

Why a shallow-rooted cactus can survive from strong wind?

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Flow measurement

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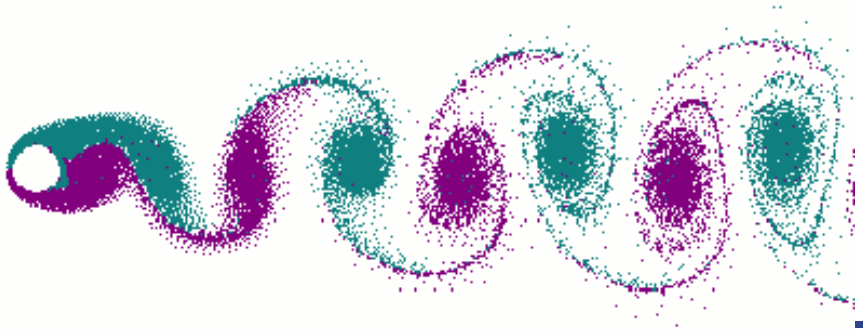
Karman Vortex Street (卡门涡街)

- When fluid (water/air) flow pass a body, it sheds (脱落) alternating (交替的) vortex (漩涡) into the wake (尾流) with certain frequency
- Periodical shedding vortex imposes a periodical force on the body
- The body resonates with vortex if the natural frequency of the body matches to the vortex shedding frequency



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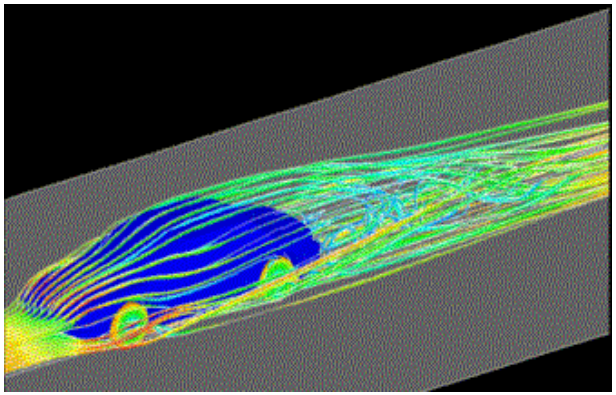
Flow measurement

- Human beings reply on seeing, feeling, hearing and tasting to understand new things
- Flow measurement is a technique to help people to **SEE:**
  - How does wind flow pass an automobile



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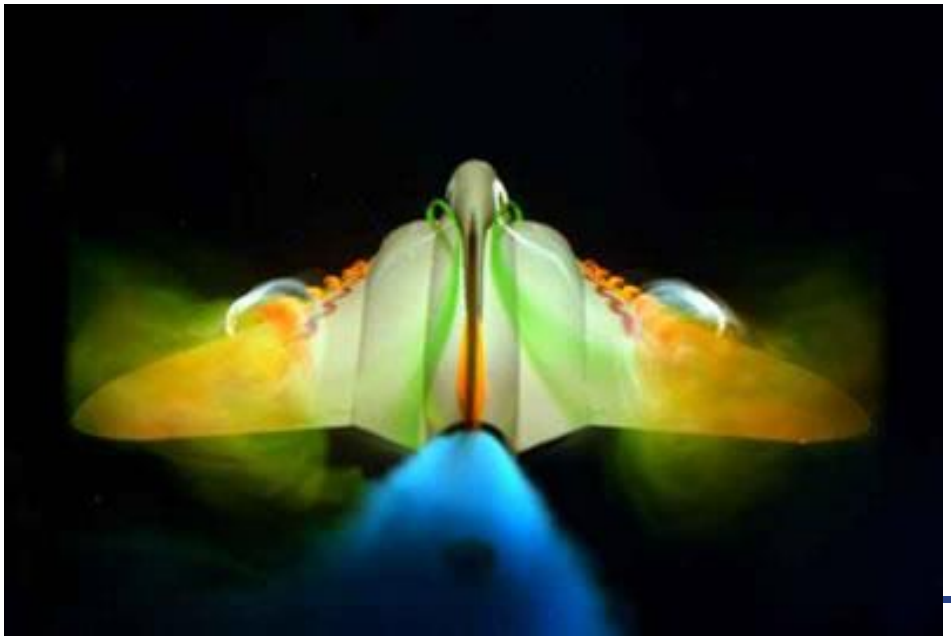

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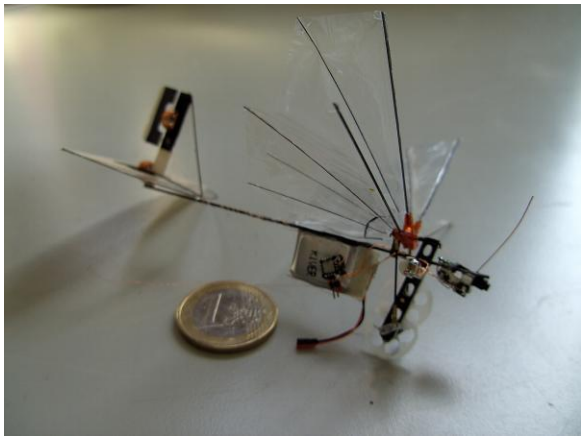
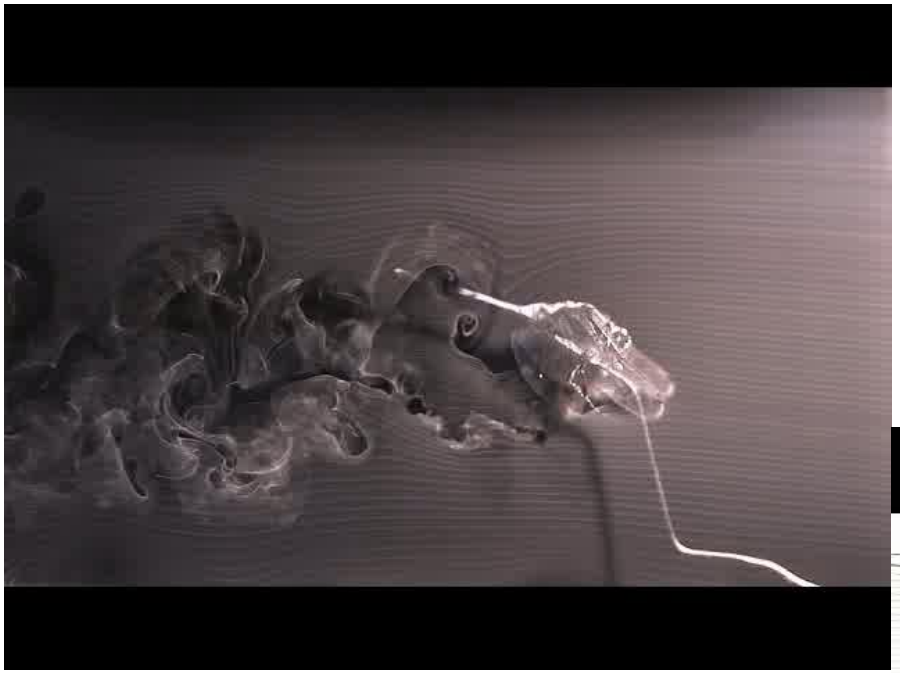
  - Why insects (e.g. dragonfly) can fly so agilely





Flow measurement

Flow measurement of a tethered flying dragonfly



A tethered flying UAV

Flow measurement

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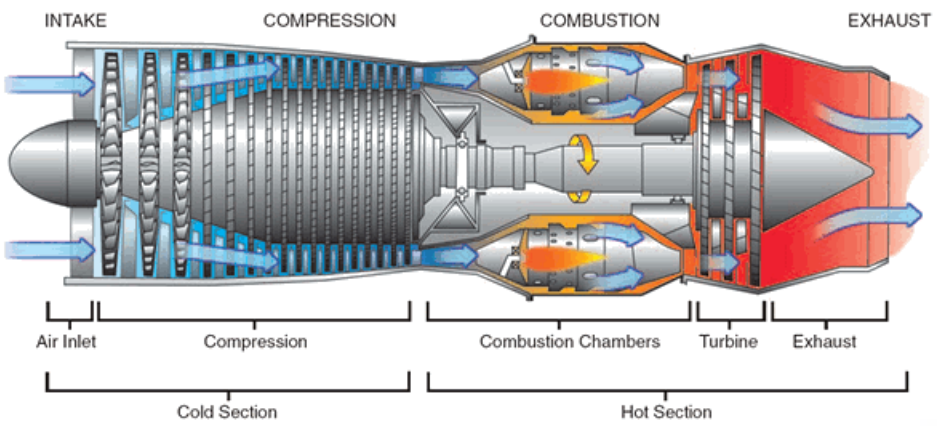
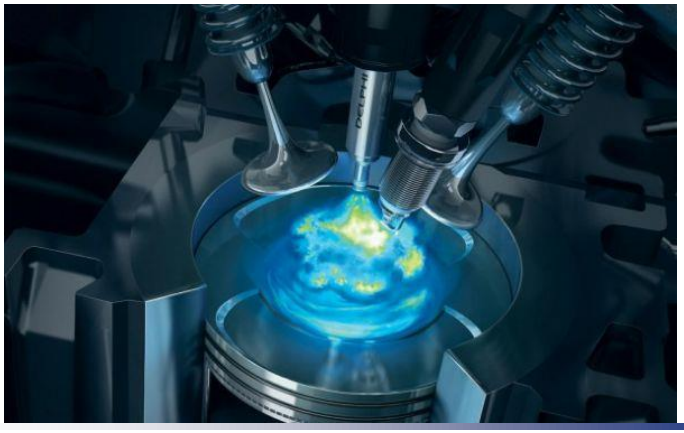
  - How the performance of an aircraft is affect by airflow around it
  - Why insects (e.g. dragonfly) can fly so agilely
  - How air and oil is mixed inside a combustion chamber





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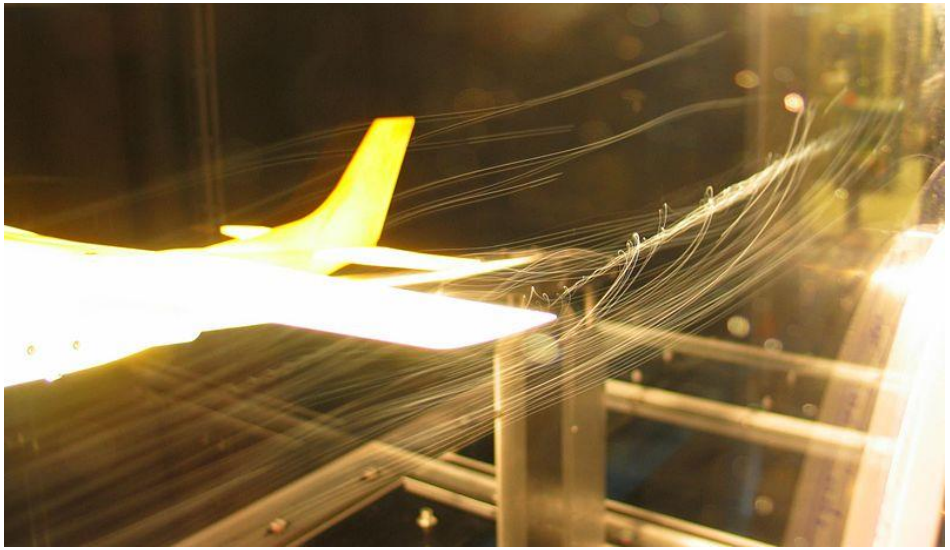
Flow visualisation

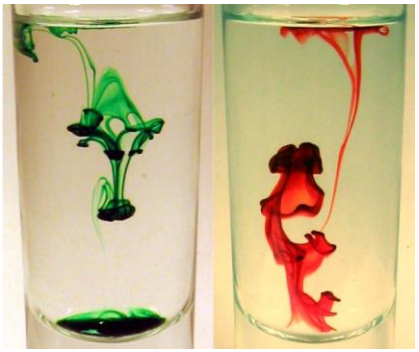
- Most fluids, gaseous or liquid, are transparent media
- Their motion is invisible to the human eye
- Techniques made the flow motion visible is referred to as

Flow Visualisation



Flow visualisation

- tracer particles are added into the fluid of interest
- motion of tracer particles are made visible to eyes or camera by illumination
- methods are taken to ensure the tracer motion is identical to that of the fluid



Making liquid flow (water) visible

- Tracer particles

  Food coloring, ink, fluorescent tracers

  Hydrogen bubble

- Releasing methods

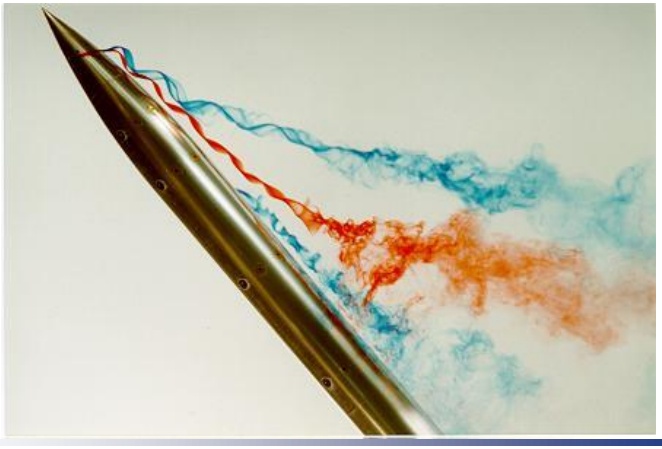
  Direct injection by syringe (注射器) (D<1mm)

  Releasing rate close to the average flow speed

  Releasing location

  Disturbance to the flow

  Use milk to retard (减缓) diffusion of the dye



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Flow visualisation

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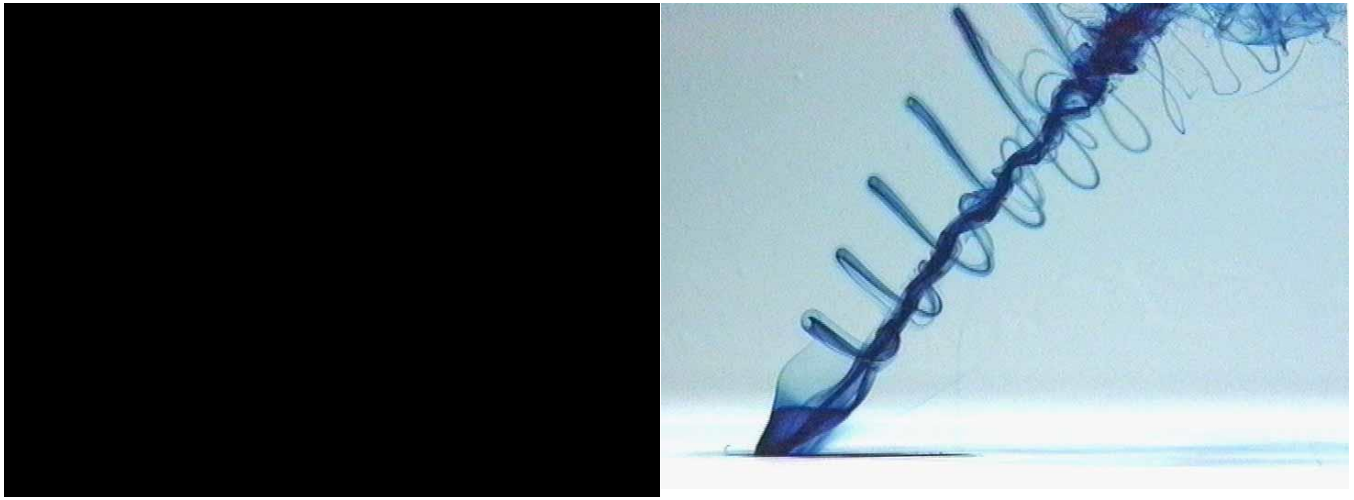
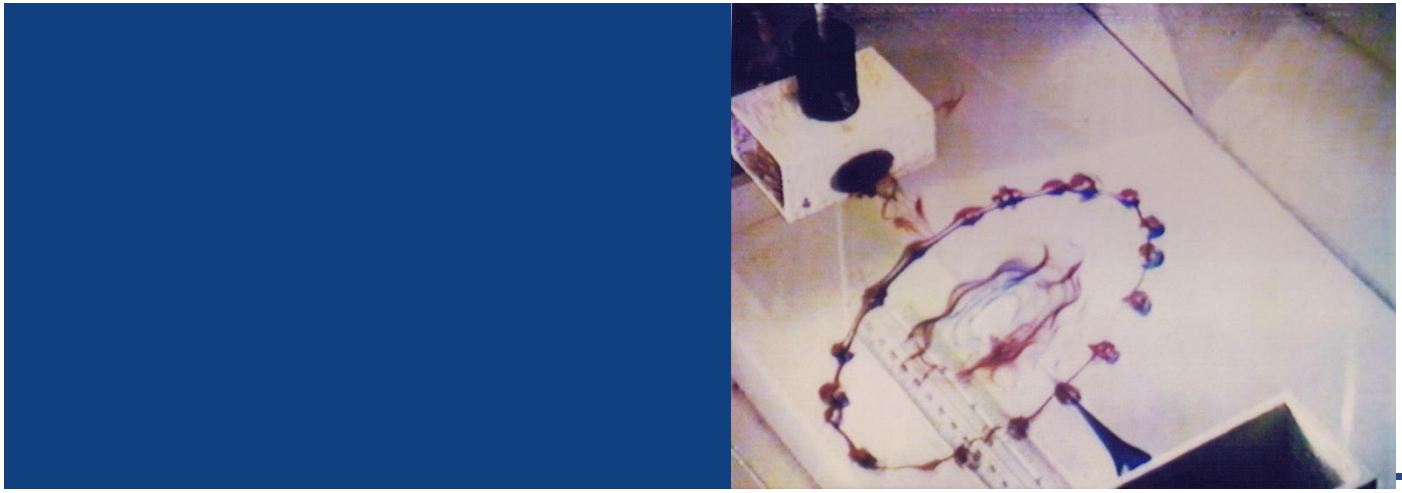
Art of Flow visualisation

Vortex ejected into cross flow

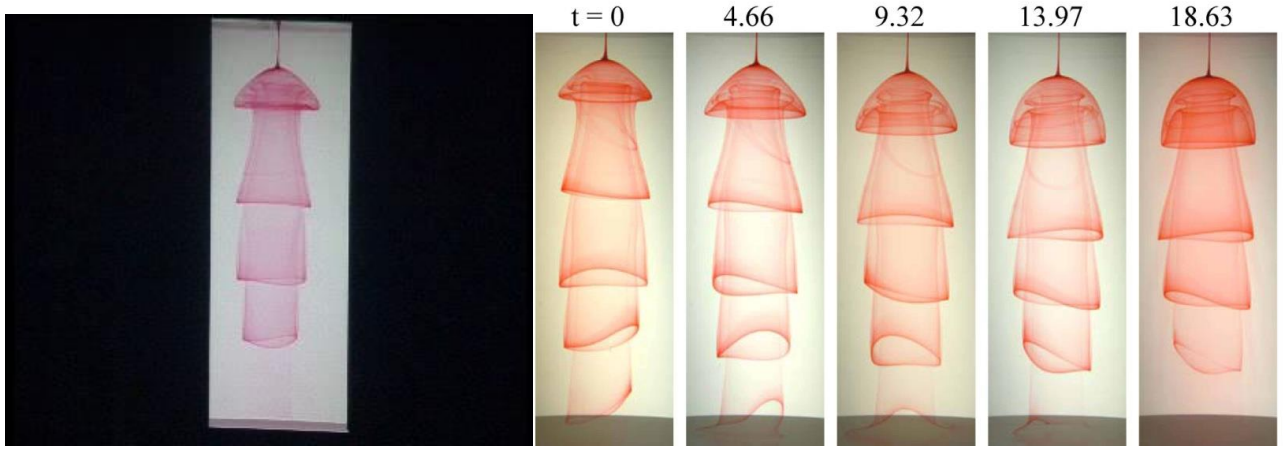


Collision of two vortex



Art of Flow visualisation

Oscillation of vortex break down



Stories behind the vortex

- Mix enhancement
- Noise reduction
- Infrared stealth

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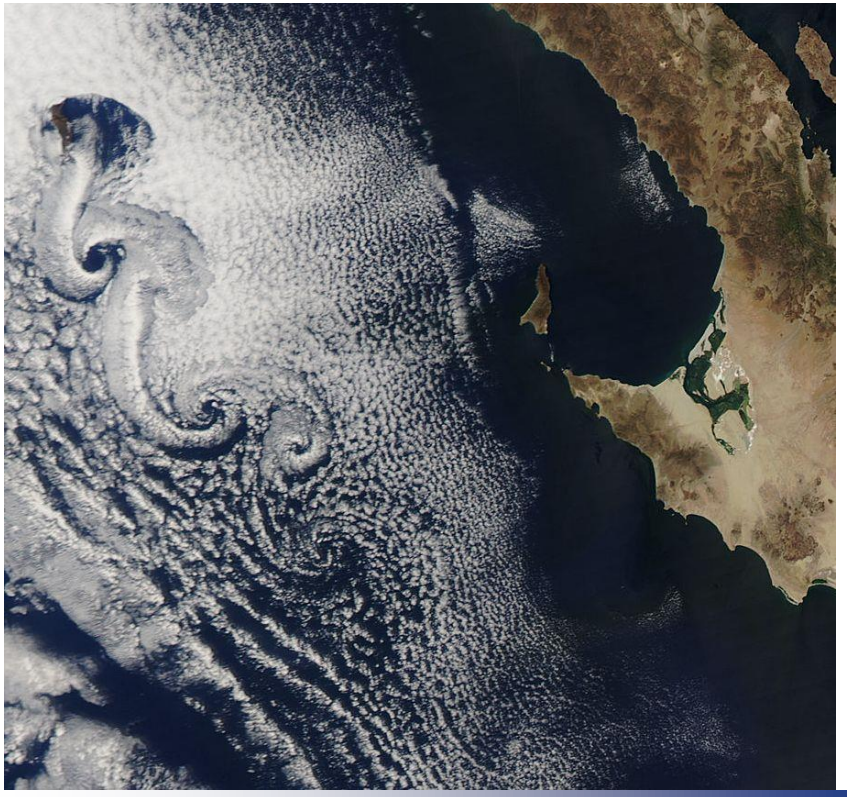
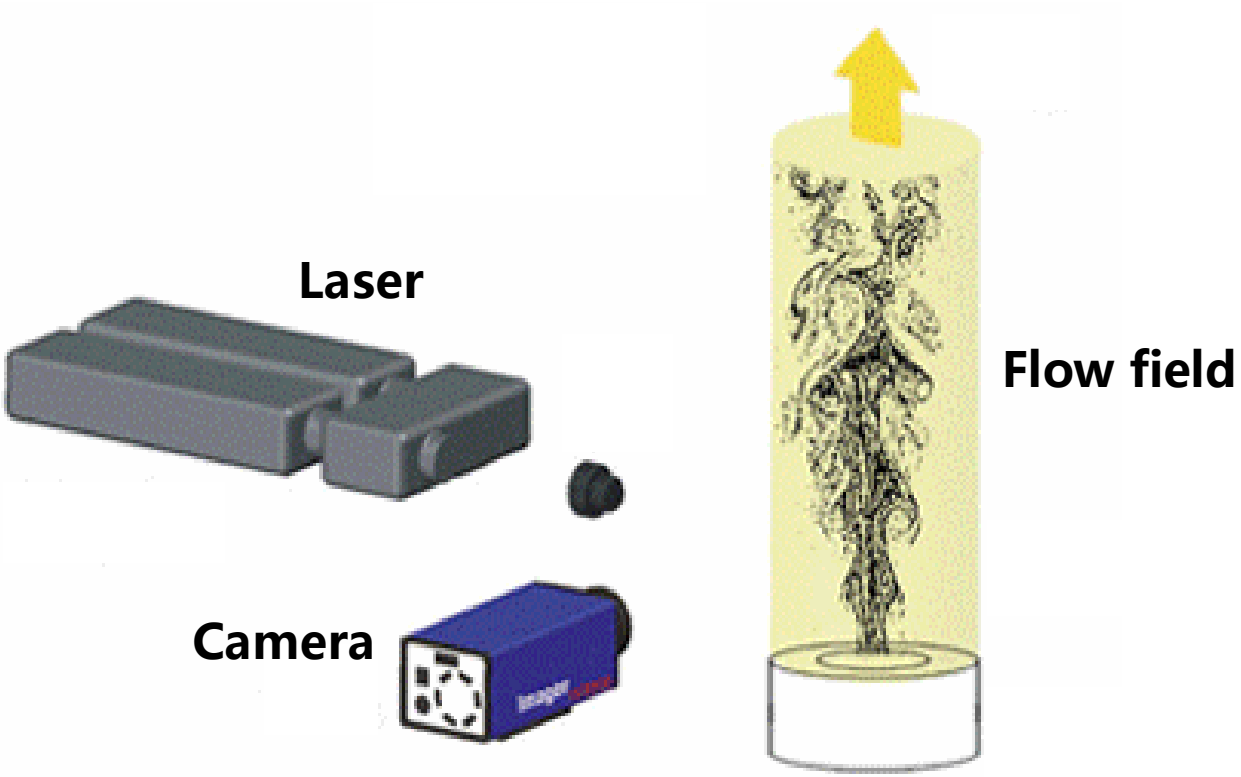
Art of Flow visualisation

Open field experiment: smoke visualization of vortex formation during the start of an airplane

Karman vortex street formed in the wind downstream of an island

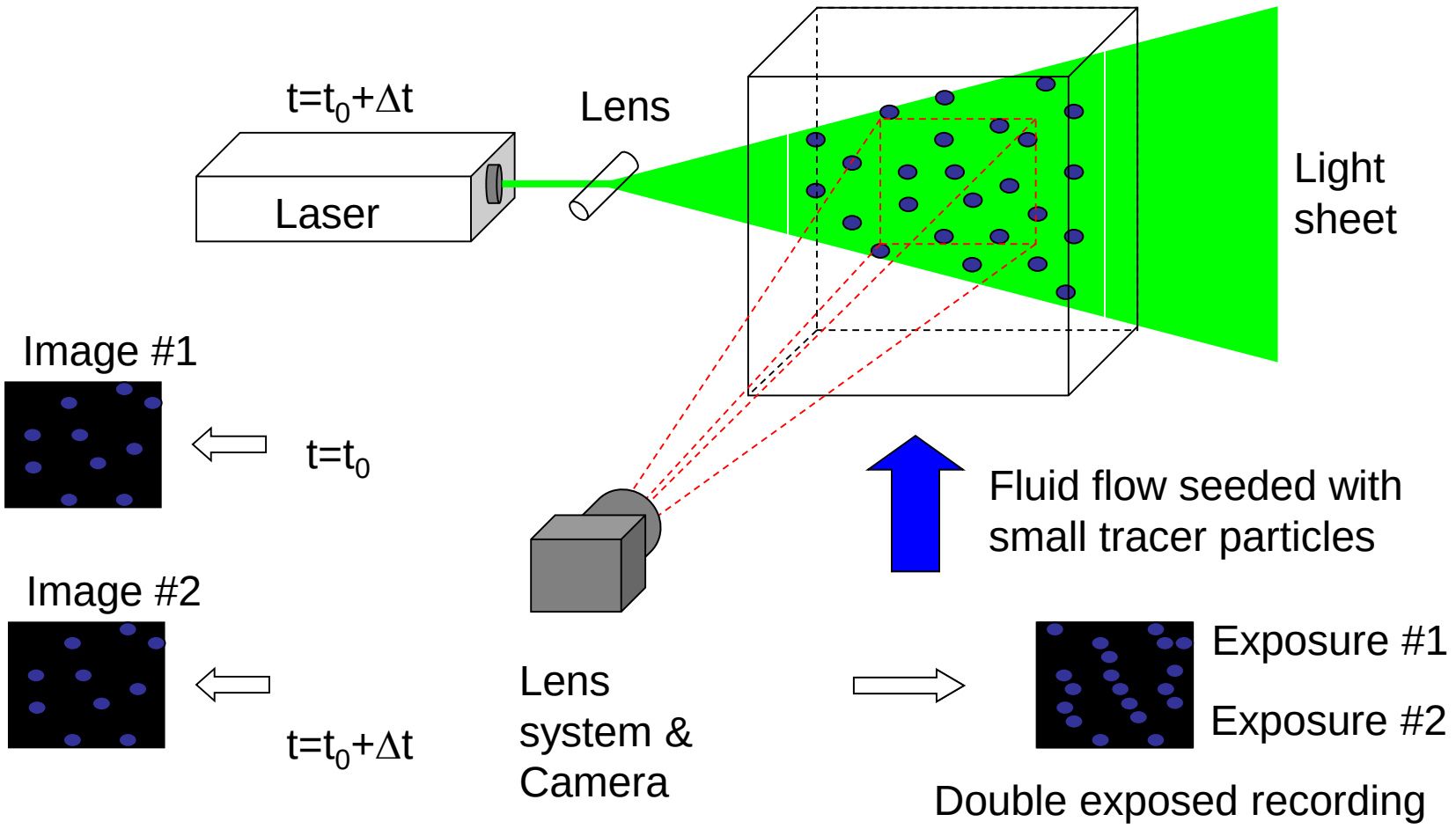


Particle Image Velocimetry



Particle Image Velocimetry

Basic Principle (2D PIV)



PIV image processing

2D cross correlation

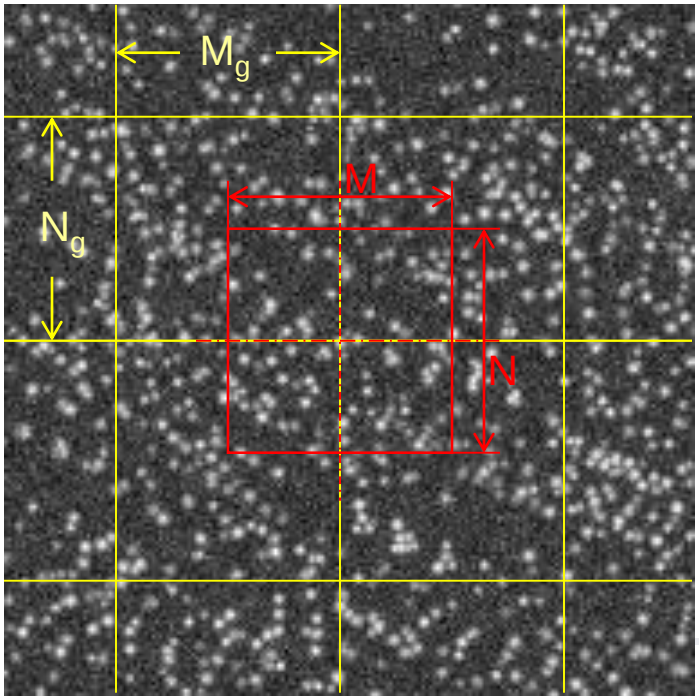
Basic principle

- Similarity of a particle image group between two frames

Procedure

- two frames are divided into small windows (e.g. 32X32 pixel)

PIV recording



Interrogation grid ($M_g \times N_g$)

Interrogation window ($M \times N$)

PIV image processing

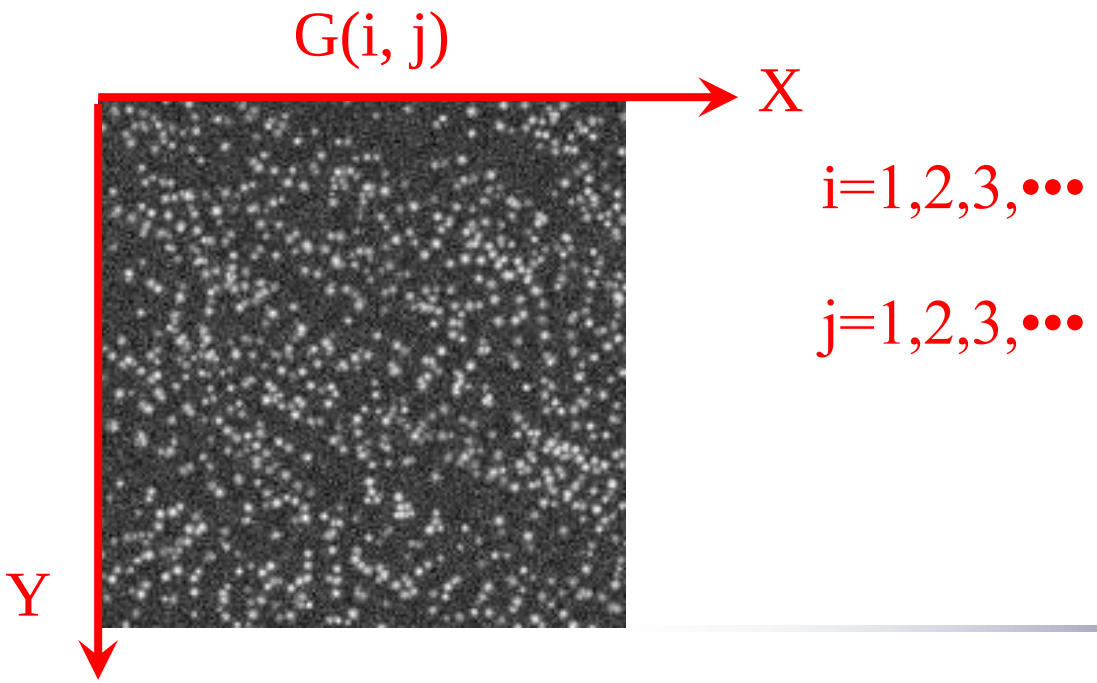
2D cross correlation

Basic principle

- Similarity of a particle image group between two frames

Procedure

- two frames are divided into small windows (e.g. 32X32 pixel)
- each interrogation windows are cross correlated



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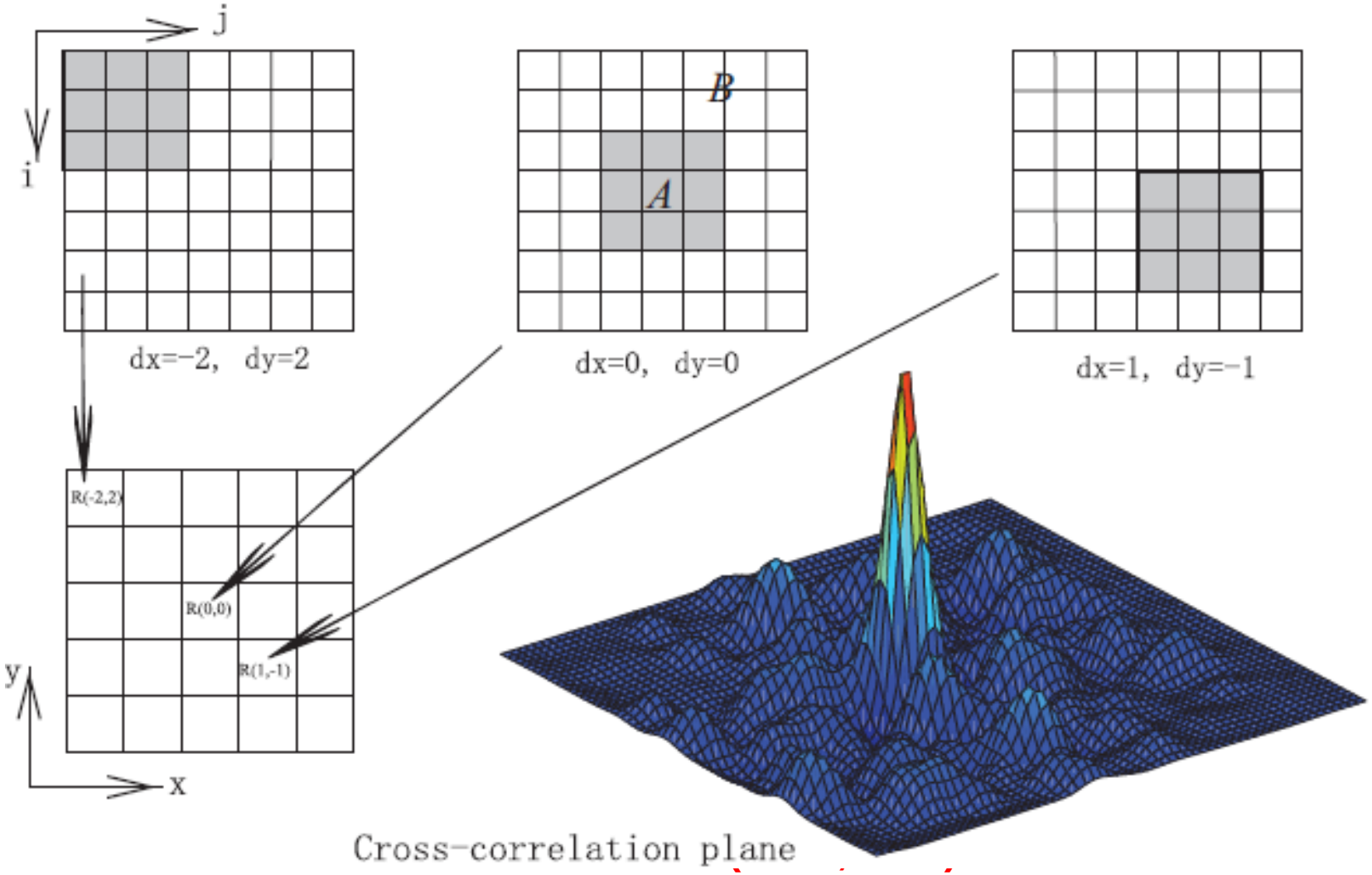

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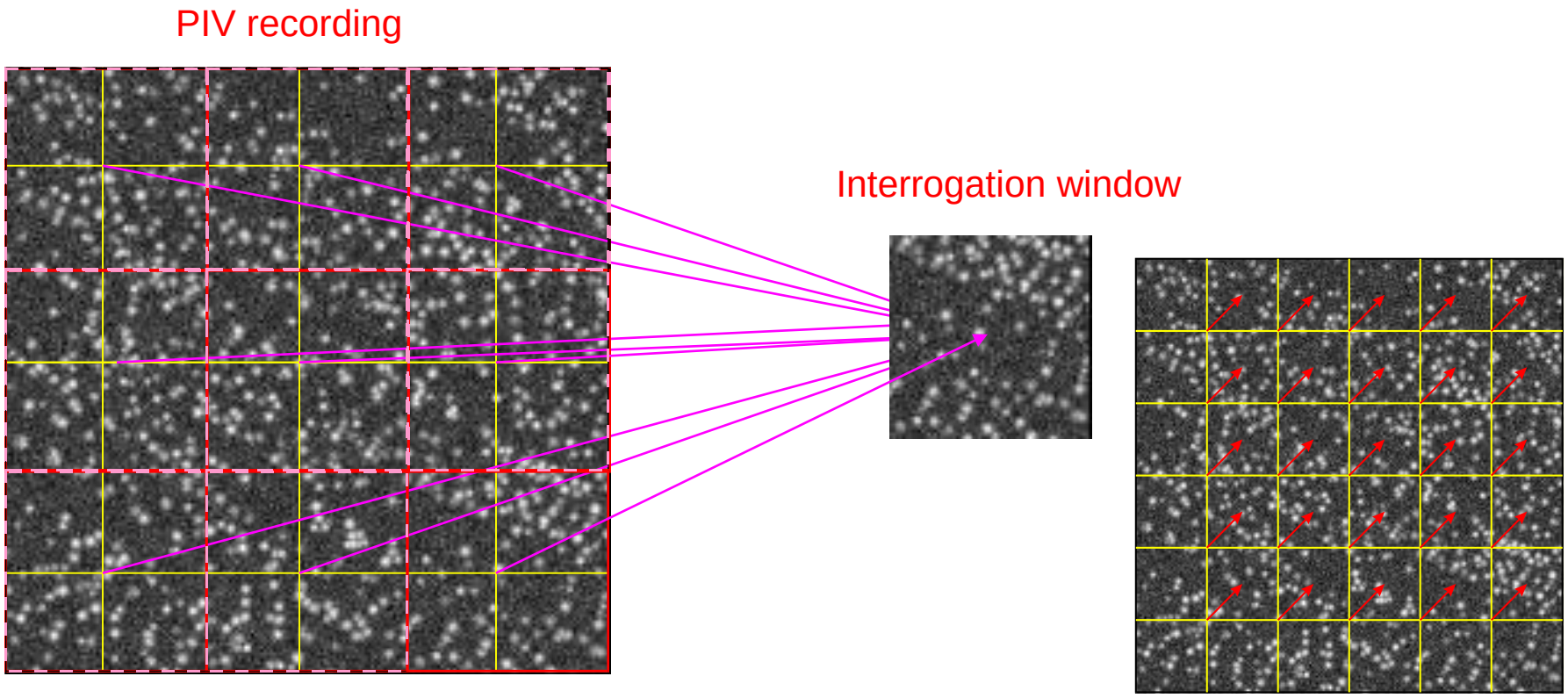
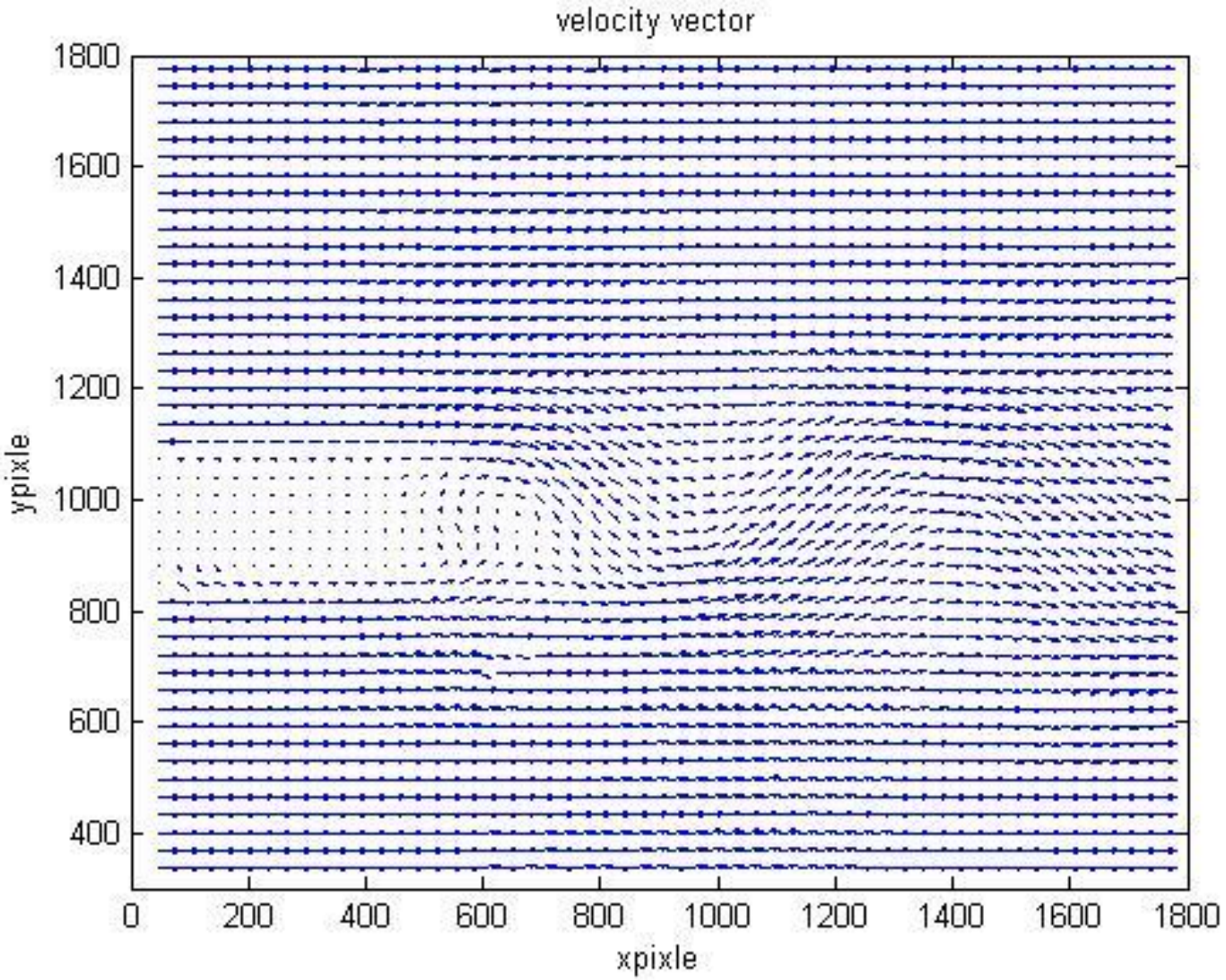


Matlab Codes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