Particle Image Velocimetry
for
Microscale Blood Flow Measurements
Overview

• Motivation
• Technique
• Results
Motivation – Proposition

Fluid forces determine gene activation.

blood flow

shear forces

detection/relation

endothelial cells

gene expression

development e.g. cardiogenesis

regulation e.g. thermoregulation

pathology e.g. atherosclerosis
Motivation – Cardiogenesis
Motivation – Fluid Forces

Shear forces can be deduced from spatial velocity measurements:

\[ \tau = \eta \cdot \frac{\partial u}{\partial n} \]

Conclusions on the relation between flow induced shear forces and the gene activity:

Gene expression of a transcription factor for cell proliferation and differentiation.
Technique – PIV

- flow
  - optical access

- tracer particles
  - visibility
  - inertia, buoyancy
  - compatibility

- illumination
  - brightness
  - exposure time

- optics/camera
  - resolution
  - light sensitivity
  - magnification
  - measurement plane
Technique – PIV

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Technique – Evaluation

procedure
1. division into small interrogation windows
2. cross correlation of interrogation windows
3. correlation maximum gives displacement
4. division by time difference gives velocity

quality
image
- particle density
- signal to noise ratio
- particle displacement
- particle size
evaluation
- window size
- correlation averaging
- multi pass correlation
- depth of correlation
Technique - Result
Technique – Practice

- dorsal aorta
- heart
- eye
- vitelline vessels

0 sec

5 mm
Technique – Tracer Particles

- fluorescence (distinction from background light based on wavelength)
- polyethylene-glycol coating (bio-compatibility)
- diameter 1 μm (measurement resolution)

mammalian red blood cell

polystyrene tracer particles

avian red blood cell
Technique – Set-up

- acquisition pc with timing unit
- double frame CCD-camera
- Nd:YLF-laser (527 nm)
- diffuser plate
- dichroic mirror
- microscope housing
- mono-/stereo objective mount
- opened egg with embryo
- tempered water bath
Technique – Set-up
Results – Measurement Domain

- 14 parallel planes
- 162 µm thick layer
Results – Example Image

- $t = 0$
- plane 11/14
- position = -127 $\mu$m
Results – Example Image

- $t = 0.5 \text{ ms}$
- plane 11/14
- position = -127 $\mu$m
Results – Temporal Reconstruction

![Time-Series of PIV Evaluations](image1)

![Peak Fitting](image2)

![Frequency Analysis](image3)

![Reconstructed Heart Beat](image4)
Results – Vector Map

- correlation result
- plane 8/14
- time step 1/24 (systole)
- position = -89 µm
Results – Three Dimensional Flow

- out of plane velocity
- mass conservation
- plane 8/14
- time step 1/24 (systole)
- position = -89 µm
Results – Three Dimensional Flow
Acknowledgments