Implementation of a Highly Parameterized Digital PIV System On Reconfigurable Hardware

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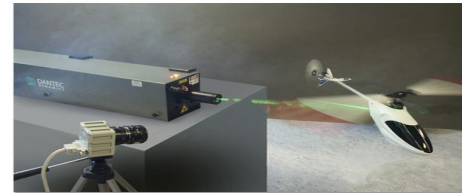
PIV: Particle Image Velocimetry

- **Engineering applications:**

    - **Aerodynamics**

    lifting aircraft wing   **Rotor aerodynamics**

    - **Optimizing combustion systems, ...**
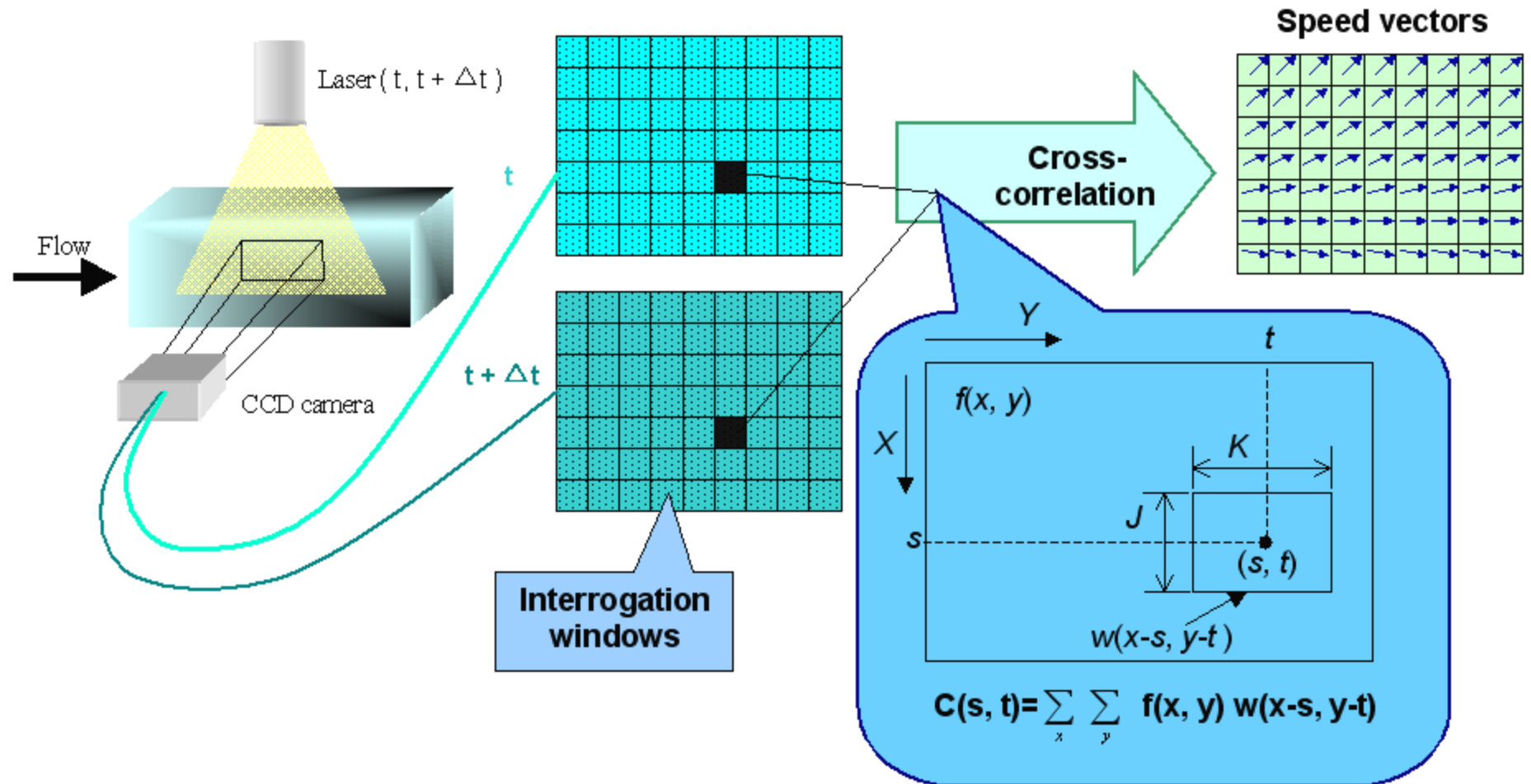
  - **Used in scientific investigations:**

    - **Animal locomotion in fluids (swimming, flying)**

   - **Studying ocean waves, thermal convection, ...**

- **The algorithm:**

    - **Is computationally intensive**

    - **Exhibits of a high degree of parallelism**

    - **Requires different parameters for different uses**

PIV Overview

Laser $(t, t + \triangle t)$

Flow

CCD camera

t

$t + \triangle t$

Interrogation windows

Cross-correlation

Speed vectors

Y

X

$f(x, y)$

s

t

K

J

(s, t)

$w(x-s, y-t)$

$$C(s, t) = \sum_x \sum_y f(x, y)\, w(x-s, y-t)$$

Parameterized Implementation

- **Parameterize hardware components:**
  - **Finite state machines, mulitpliers, accumulators, dividers**

- **Parameters:**
  - **Image size**
  - **PIV specifics:**
    interrogation area, displacement
  - **Board specifics: memory bandwidth ...**
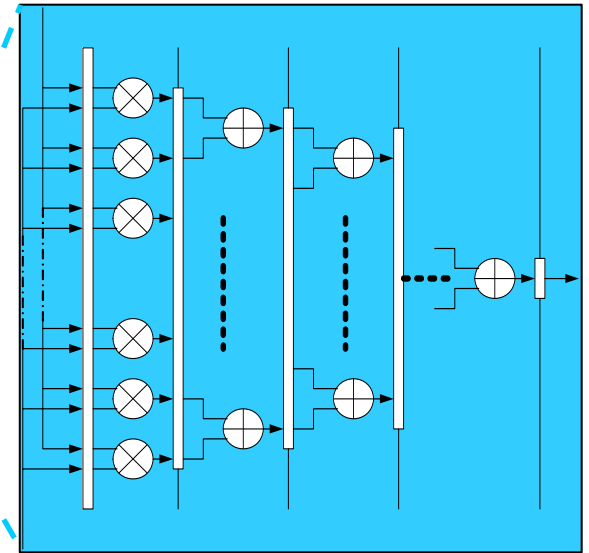
Circuits	Image size	Hardware latency	Software Latency	Speedup
1	1024x1024	0.025	3.21	128
2	1200x1600	0.027	3.76	139
3	400x50	0.00473	0.109	23

Implications and Applications

- **PIV analysis has always been offline post-processing**
- **High frame rates (>30 Hz) and small latencies (<0.03s) are sufficient for *real-time optical feedback control***
  - **Enables many novel experiments in flow control**
  - **Current laboratory experiment with MIT: an underwater vehicle which can "swim" efficiently through a complicated fluid environment by sensing the oncoming flow**

Water table setup at MIT