Introduction

- Digital image correlation (DIC) is a popular and efficient technique for motion and deformation measurements as it provides sub-pixel accuracy. But it represents a significant drawback, extremely huge computational (iterative algorithm, ...).
- The current solution consists on off-line processing.

Objectives

- Field-Programmable Gate Array (FPGA) for real-time: parallelism, pipeline

DIC principle

- Track each image pixel by comparing gray level values of the images taken before and after deformation.
- Many pixels in the deformed image may have the same gray level value, hence neighboring pixels are used.

![Subset Tracking](image)

DIC is based on minimizing the gray value difference between a reference subset and deformed subset [1]:

\[ U(X_0) = \arg\min_{\text{ROI}} \sum_{i} |f(X_0) - g(X_0 + U(X_0))|^2 dX_0 \]  

(1)

Algorithm

![DIC algorithm](image)

Interpolation

<table>
<thead>
<tr>
<th>Method</th>
<th>Bi-linear</th>
<th>Bi-cubic</th>
<th>B-spline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>Low</td>
<td>Complex</td>
<td>Difficult to implement</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Low</td>
<td>High</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Table 1: Interpolation methods [2]

Results (Matlab)

![Translation of [1.503,0.701]](image)

![Rotation of 0.5°](image)

Implementaion of Bi-cubic interpolation

- Hardware architecture
- Mathematic reformulation
- Avoiding redundant computations
- Coefficients block
- 5 bi-cubic sub-block

![Bi-cubic sub-block](image)

The algorithm is coded in VHDL and implemented into FPGA Cyclone V

<table>
<thead>
<tr>
<th>Image size</th>
<th>Frequency max</th>
<th>DSP(18x18)</th>
<th>Logic (ALMs)</th>
<th>Memory (bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1024x1024</td>
<td>204 MHz</td>
<td>15 (17%)</td>
<td>1786 (6%)</td>
<td>30657 (&lt; 1%)</td>
</tr>
</tbody>
</table>

Table 2: Resources utilization report

Conclusion and perspectives

- Bi-cubic interpolation is selected because it represents the best trade-off between complexity and accuracy. Our proposed architecture improves the operating frequency [3] and it is well suited for practical real-time applications such as DIC.
- As a perspective, the implementation of DIC based on bi-cubic interpolation is envisaged.

References


Contact Information

- Email: seyfeddine.boukhtache@uca.fr