Seminar of Parallel Programming

Parallel algorithms for stereo vision

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4 “What” 1 “How” & 1 “Why”

- What is StereoVision
- What's the difference between stereovision and normal vision.
- What is to be done (Stereo vision)
- Why we need it (Parallel)
- How it works
- What is the result
What is “stereovision”

Stereovision is the process in visual perception leading to the sensation of depth from the two slightly different projections of the world onto the retinas of the two eyes.
Two images from camera

- Left
- Right
Mix them directly
Two images from camera

- Left
- Right

Pair of synthetic stereo images

Visible difference

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Stereo Vision - What is to be done?

1. Selection of proper distance between cameras and of proper focal lengths of the lens system
   The stereo vision experiment has to be set-up such, that the objects to be reconstructed are imaged by both cameras and the depth resolution satisfies the requirements of the application.

2. Geometric Camera Calibration
   It is essential the exact geometry of the cameras relative to the world is known and that any non-linear distortions of the projection may be inverted.

3. Finding conjugate pairs
   Constraints need to be posed for resolving ambiguities that arise when corresponding locations are to be found.

4. Depth (location) computation
   Computation by triangulation

(5. Surface Computation)
   3-d information at locations, where the correspondence problem is solved, may be input for computing continuous surfaces of the visible part of the object and may help to infer the complete surface.
- Cyclopean View
Cyclopean View & Overlay
Two images from two “eyes”
Depth (OpenCV `cvFindStereoCorrespondence`)
What we can do

- Real-time stereovision
- Parallel
Cluster architecture

![Diagram of cluster architecture](image-url)
```cpp
struct Data : public MPIData<Data>
{
    Frame input;
    Frame output;
};

struct Work : public Task<Work>
{
    bool operator()( Data& d )
    {
        d.output = where(d.input > 127, 255, 0);
        return true;
    }
};

int main(int argc, const char** argv )
{
    Data d;
    Camera camera( 30, res640x480, 8 );
    Cluster cluster(argc, argv);

    task_list(RowSplit<Frame>,Work,RowMerge<Frame>) act;
    cluster.task() = (SCM<act>(cluster.root(),cluster.world()));

    camera >> d.input;
    cluster.run(d);

    return 0;
}
```
A cluster synchronization step

By using a message passing based synchronization (using MPI_Barrier) to force all nodes to wait each other before acquiring the next frame we force the synchronization of frame acquisition on all nodes. This synchronization has to be explicitly triggered by the user.
## Result

<table>
<thead>
<tr>
<th>Step</th>
<th>Seq</th>
<th>np=2</th>
<th>np=4</th>
<th>np=8</th>
<th>np=16</th>
<th>np=24</th>
<th>np = 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECTIF</td>
<td>246 ms</td>
<td>139.1 ms</td>
<td>70.5 ms</td>
<td>36.1 ms</td>
<td>19.5 ms</td>
<td>13.1 ms</td>
<td>12.6 ms</td>
</tr>
<tr>
<td>DETECT</td>
<td>262 ms</td>
<td>80.1 ms</td>
<td>40.5 ms</td>
<td>20.6 ms</td>
<td>11.2 ms</td>
<td>7.1 ms</td>
<td>6.4 ms</td>
</tr>
<tr>
<td>MATCH</td>
<td>304.2 ms</td>
<td>180 ms</td>
<td>91.5 ms</td>
<td>47.4 ms</td>
<td>22.4 ms</td>
<td>13.8 ms</td>
<td>9.7 ms</td>
</tr>
<tr>
<td>BUILD</td>
<td>180 ms</td>
<td>100 ms</td>
<td>53 ms</td>
<td>27.5 ms</td>
<td>18.2 ms</td>
<td>12.0 ms</td>
<td>9.5 ms</td>
</tr>
<tr>
<td>TOTAL</td>
<td>992.2 ms</td>
<td>479.2 ms</td>
<td>244.6 ms</td>
<td>122.6 ms</td>
<td>68.2 ms</td>
<td>42.9 ms</td>
<td>38.2 ms</td>
</tr>
<tr>
<td>FPS</td>
<td>1.02</td>
<td>2.08</td>
<td>4.08</td>
<td>8.15</td>
<td>14.66</td>
<td>23.31</td>
<td>26.17</td>
</tr>
</tbody>
</table>
Example of the Cyclopean View
Ref.

Rolf Hekel's Stereovision
http://axon.physik.uni-bremen.de/index.htm

3D Vision
http://e-spacy.com/blog/3d-stereo-visual-to

Vision3D
http://www.vision3d.com/stereo.html

Stereopsis,Wikipedia
http://en.wikipedia.org/wiki/Stereopsis

3D Computer Vision, 5. Stereo Vision
(Introduction), Klaus D. Toennies
Shape and the stereo correspondence problem, Abhijit S. Ogale and Yiannis Aloimonos

Real-Time Correlation-Based Stereo Vision with Reduced Border Errors, Heiko Hirschmüller, Peter R. Innocent and Jon Garibaldiu
Computing $Z$ from the disparity

Application of the intercept theorem (with $x_l-x_r$ equalling disparity $d$):

$$\frac{Z}{Z+f} = \frac{b}{b+x_l-x_r}$$

$\iff Z (b+x_l-x_r) = b (Z+f)$

$\iff Z (x_l-x_r) = bf$

$\iff Z = \frac{bf}{x_l-x_r} = \frac{bf}{d}$
Thank you for listening.