CUDA-Accelerated Acquisition of Spread Spectrum Signal in Satellite Communication

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1. Spread Spectrum Communication

Spread spectrum techniques deliberately spread a signal with a particular bandwidth into a signal with wider bandwidth. Due to more secure communication and enhanced resistance to natural interference, noise and jamming, spread spectrum signal has been used in many applications in satellite communication, e.g. Global Positioning System.

2. Acquisition Algorithm

```c
for(int ch = 0; ch < # of channels; ch++){
    for(int i = 0; i < needLen; i++)
        PNcode[i] = pData[i*floor(modf((float)prRate* (1.0+(channels[ch]*ft)])/fs)*1023.0)];
    mix_L[i] = sin(2*PI*(f0+channels[ch])*fs+phase0)*s[i];
    mix_Q[i] = cos(2*PI*(f0+channels[ch])'/fs+phase0)*s[i];
}
for(int j = 0; j < pointCodeN; j++)
    for(int t = 0; t < NL * NA; t++)
        mi_L[t] = localGold[t] * mix_L[j*pointCode'+ t];
    mi_Q[t] = localGold[t] * mix_Q[j*pointCode'+ t];
}
for(int k2 = 0; k2 < NL; k2++)
    for(int k1 = 0; k1 < N; k1++)
        tmpL = 0.0; tmpQ = 0.0; n = k1*sumL + k2*NA;
    for(int p = n; p < n + sumL; p++)
        tmpL += mi_L[p]; tmpQ += mi_Q[p];
    dataQ[NL*N*j+k1+k2*N] = tmpL;
    dataQ[NL*N*j+k1+k2*N] = tmpQ;
}

// select the max value from Rout, then its position is acquired.
```

3. CUDA enabled Parallel Acquisition Algorithm

**Complexity:** $O(NL*NA*pointCodeN*channels)$

**Phase 1: Mixing (parallelism: needLen)**
- Each thread calculates three elements in three vectors: PNcode, branch I of the mixed signal, branch Q of mixed signal.

**Phase 2: Sliding Correlation (parallelism: pointCodeN*NL)**
- Each thread calculates a dot product of sumL pairs of points.
- Different threads in a block take different segments of mix_I/O.
- Load the segment of mix_I/Q into the shared memory on an SM.
- All the threads in a block share a common segment of the PNcode, load the common part into the shared memory on an SM.

**Phase 3: FFT-based Acquisition (parallelism: pointCodeN*Nfft)**
- Perform FFT on dataI and dataQ by invoking CUFFT in batch mode.
- Each thread computes the modulus of NL signal points, and accumulates the moduli.

4. Performance Evaluation

- Six sets of data with 56M/s sampling rate from a real telemetry system
- 300 microseconds, each set containing 8192*2048 floats

**Speedups on K20**

Real-time acquisition was achieved in most cases!

<table>
<thead>
<tr>
<th>Data Set</th>
<th>CPU (ms)</th>
<th>CU-AcqSS (ms)</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15,902</td>
<td>76.255</td>
<td>208.537</td>
</tr>
<tr>
<td>2</td>
<td>19,552</td>
<td>142.687</td>
<td>137.027</td>
</tr>
<tr>
<td>3</td>
<td>27,431</td>
<td>128.921</td>
<td>212.774</td>
</tr>
<tr>
<td>4</td>
<td>30,206</td>
<td>176.481</td>
<td>176.148</td>
</tr>
<tr>
<td>5</td>
<td>39,755</td>
<td>245.084</td>
<td>162.210</td>
</tr>
<tr>
<td>6</td>
<td>36,763</td>
<td>396.639</td>
<td>92.686</td>
</tr>
</tbody>
</table>

Counterpart: CPU version using Intel® IPP

**Scalability when increasing NL and PointCodeN**

Linear scalability!

**Conclusion**

- Identified the computational core of the acquisition algorithm, sliding correlation
- Proposed an efficient scheme to accelerate sliding correlation on CUDA
- Implemented the acquisition algorithm on CUDA
- Evaluated on 6 sets of data
- Up to 212X speedups were observed
- Good scalability was observed when varying the computation
- Real-time acquisition was achieved in most cases