Synthesis Instrumentation Testbed For Chirp Signal Applications Using MPI Cluster and Planetlab

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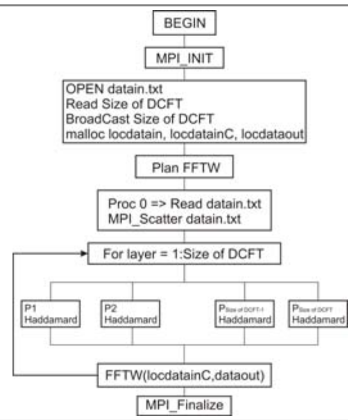
1 Problem Formulation

The necessity of tools for signal processing using the advantages of distributed environments is very important. Many signal processing operators involve large computational complexity and the distributed environments such as PlanetLab constitutes a powerful tool suitable to be used.

A Time-frequency signal is defined as a signal whose spectral distribution changes with time. Chirp signals are time-frequency signals which are linearly frequency modulated and are widely used in RADAR applications. The 1-D Discrete Chirp Fourier Transform (DCFT) operator that make possible from Chirp signals the extraction and estimation parameters of one component or multicomponent signals arriving from point targets. The formulation of Discrete Chirp Fourier Transform (DCFT) algorithms and the mapping of these algorithms to hardware computational structures (PlanetLab and/or MPI Clusters) is our job.

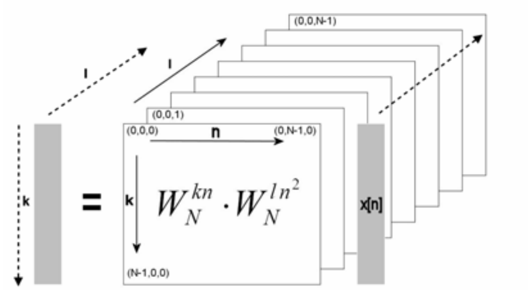


2 Theoretical Framework

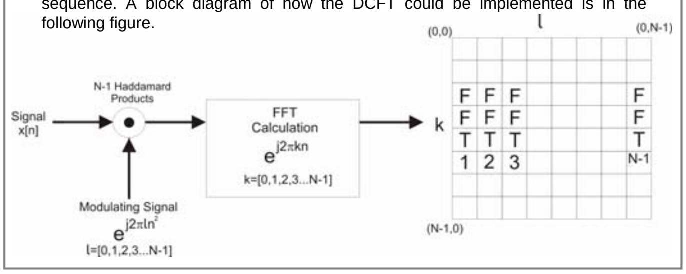
The 1-D DCFT[1] is defined as:

$$X_C[k,l] = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x[n] \cdot W_N^{l \cdot n^2 + kn} \qquad 0 \le k, l \le N-1$$

From the definition of the DCFT we have that the input signal is 1-D and is mapped into a 2-D output signal. A graphical interpretation of how the index of the transform variates is bellow:



The DCFT as a first approach could be seen as N-1 FFT of complex sequences[3]. The complex sequences are obtained as a Haddamard product of the input sequence. A block diagram of how the DCFT could be implemented is in the following figure.



3 Proposed Solution

The solution of the DCFT is a computational complex problem. As we can see in the following table:

	DFT	FFT	DCFT- DEF	DCFT-IMP
samples	**n²**	**nlog(n)**	**n³**	**n²log(n)**
1024	1.05E+06	1.02E+04	1.07E+09	1.05E+07
2048	4.19E+06	2.25E+04	8.59E+09	4.61E+07
4096	1.68E+07	4.92E+04	6.87E+10	2.01E+08
8192	6.71E+07	1.06E+05	5.50E+11	8.72E+08
16384	2.68E+08	2.29E+05	4.40E+12	3.76E+09
32768	1.07E+09	4.92E+05	3.52E+13	1.61E+10
65536	4.29E+09	1.05E+06	2.81E+14	6.87E+10
131072	1.72E+10	2.23E+06	2.25E+15	2.92E+11
262144	6.87E+10	4.72E+06	1.80E+16	1.24E+12

Table 1. Computational complexity of the FFT and the DCFT

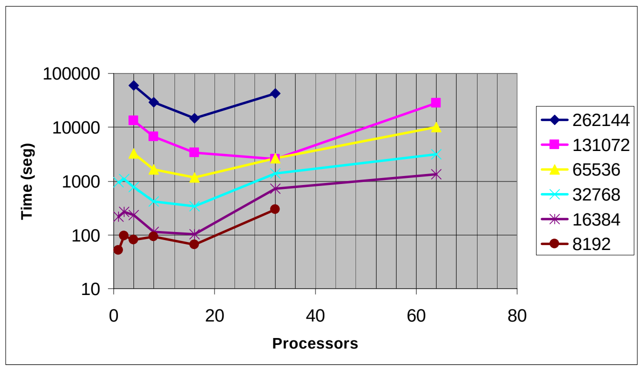
A cluster implementation of the DCFT has been tested in the High Performance Computer Facilities at UPRM in a Linux Cluster Computer. The implementation was made in MPI using the FFTW[2] Libraries for the calculation of the DCFT.

4 Implementation Effort

The execution results for the DCFT implementation proposed are in the table and in the figures bellow.

Processors	**1**	**2**	**4**	**8**	**16**	**32**	**64**
Samples							
8192	51	94	81	93	66	301	
16384	216	271	236	112	101	726	1344
32768	963	1101	787	420	335	1388	3192
65536			3221	1660	1167	2651	10209
131072			13211	6641	3335	2524	27964
262144			59600	29141	14725	42214	129018

Table 2. MPI Cluster Implementation Results



5 Conclusions and Future Work

- DCFT certainly is a Problem for Cluster. In fact Cluster implementation allow calculate number of samples up to now impossible in PC implementations using Matlab® and C.
- FFTW needs of high interprocessor bandwidth to run efficiently.
- Communications play an important role in the Performance of our Application. A new implementation that reduces the communication and increase the processor load and memory resources will be interesting.
- PlanetLab® used as a multiprocessor or grid environment is the next step in this research.
- Implementation of other operators such as convolution, correlation and, ambiguity function.

6 References

[1] X.-G. Xia, "Discrete Chirp-Fourier transform and its application to chirp rate estimation", IEEE Trans. Signal Processing 48, pp. 3122–3133, Nov 2000.
[2] M. F. S. G. Johnson, "FFTW: An adaptive software architecture for the FFT", In Proc. Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 1381–1384, May 1998.
[3] N. Santiago, C. Aceros-Moreno, D. Rodriguez, "Performance measures for parameter extraction of sensor array point targets using the discrete chirp Fourier transform", Proceedings of SPIE -- Volume 6235 Signal Processing, Sensor Fusion, and Target Recognition XV, Ivan Kadar, Editor, 62351L (May. 17, 2006)

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