Current Status of Software Correlators Developed at Kashima Space Research Center

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Abstract

We have been developing two types of software correlators run on a PC. One type aims at obtaining the correlation data compatible with those processed by the hardware correlator for a geodetic use, and the other is an ultra high-speed software correlator for processing gigabit VLBI data. At present time the processing speed on a PC is about 10 Mbps for the former one and 90 Mbps for the latter one. We are now developing the distributed processing technique for further speedup to realize real-time correlation in the e-VLBI system.

1. Introduction

Raw data of the Mark I, world's first digital VLBI system developed in the U.S. in 1960's, were correlated by a computing program (software correlator). It took 90 minutes by using the main frame computer IBM360/50 to process 144 Mbits data [1]. It was equivalent to the data processing rate of 26.7 kbps. In 1980's Kashima VLBI group also developed the software correlator named CCC (Cross Correlation in a Computer) run on a minicomputer of HP1000 series [2]. It took 150 minutes to process 16 Mbits data by using a minicomputer HP1000/A900, and this corresponded to 1.8 kbps. The CCC was used in the actual fringe test of a domestic VLBI conducted in 1985, and we could successfully get fringes. However, it was not practical from the reason that not only data processing but also data transmission took time too much. We had to wait for progresses of both computing speed and data transmission speed to put a software correlator in practical use. Thereafter a personal computer (PC) shows continuous improvement in performance. Indeed, the computing speed of a recent PC is much faster than that of the workstations and minicomputers of ten years ago, and the use of a software correlator for VLBI data processing becomes realistic. Therefore we have been developing a software correlator again since 1999. Actually a software correlator with sufficient processing speed was developed and demonstrated that it could be used for a routine processing. We are also developing the distributed processing technique for further speedup to realize real-time correlation in the e-VLBI system. In this paper, we will report the current status of our software correlator.

2. Software correlators

There are two types of correlators (Figure 1). One is an XF type and the other is an FX type. The XF type correlator multiplies each time-domain data directly to obtain a cross correlation while the FX type first Fourier transforms into the frequency domain and then multiplies two frequency domain data to obtain a cross spectrum.

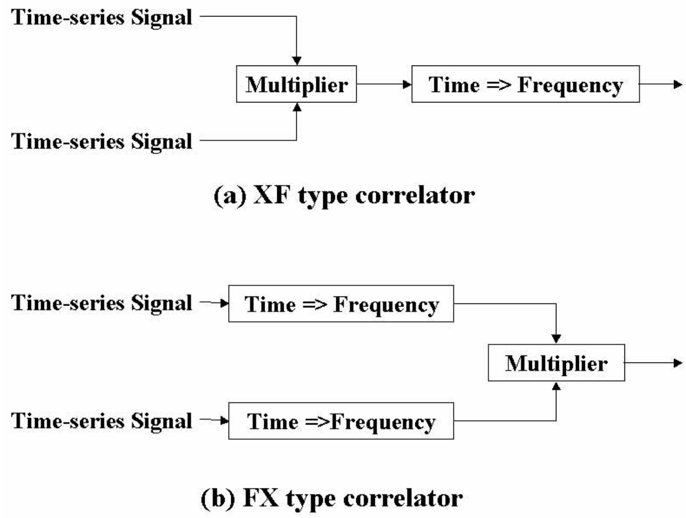

Figure 1. Two types of correlators.

2.1. XF-type software correlator

The CCC was an XF-type software correlator developed by Kashima VLBI group in 1980's for a fringe test [2]. It was developed by using the FORTRAN language on an HP-1000/45F minicomputer and was migrated to an HP-1000/A900 later. It took 150 minutes to process 16 Mbits data (i.e., equivalent to the processing speed of 1.8 kbps) by using the HP1000/A900. Therefore, we thought that it was unrealistic to use routine correlation processing. However we tested the CCC for a prompt fringe check at a Japanese domestic VLBI experiment conducted on the Kashima-Miyazaki baseline in 1986. Distance is about 1000 km, and usually it took a few days to ship a magnetic tape from Miyazaki to Kashima. To obtain the prompt result of fringe test, we sent raw data over telephone line using a 1200bps modem. It took 1hour and 21 minutes to transfer 4 Mbit data, and then data were correlated using the CCC. Finally we could successfully detect fringes only in 10 hours from an observation was ended. This was an extremely short turn around time at that time. However telephone cost was very expensive at that time in Japan, so that we never tried this e-VLBI again. The CCC was also used in the first Canada-Japan VLBI experiment using a wave-front clock technique conducted in 1990. Raw data observed at Algonquine were recorded on floppy disks and brought back to Kashima. Then the CCC was executed to get fringes. If we had enough budget for international phone communications, we could carry out an international e-VLBI at that time. As have mentioned above the CCC was successfully used for some experiments, but computing power of mini-computer at that time was insufficient to use a software correlator for routine processing of VLBI data.

Then ten years have passed, and a PC showed a drastic improvement in performance during this period. The use of software correlator thus becomes realistic, therefore we started the development of software correlator again. We have developed the PC-based VLBI data-acquisition terminal named K5 dedicated to transmitting the data through the Internet since 1999 [3]. A software correlator was planned to be used in correlation processing from the beginning of K5 development, and the software correlator dedicated to geodetic use (K5 software correlator) based on the CCC has been developed by using the C language for K5 data processing. Since the K5 software correlator aims at obtaining the correlation data compatible with those processed by the hardware correlator (i.e., not only correlation processing but also extraction of phase calibration signals is implemented), a bandwidth-synthesizing program can handle correlated data directly to get a precise observed delay.

We carried out a benchmark test of K5 software correlator for various kinds of CPUs. Results are summarized in Figure 2. Clock frequency is taken as a parameter expressing CPU power. Time required to correlate 1 sec period data of 4ch 8MHz-1bit sampling data (corresponding to 32 Mbits) was measured. Data used are 4-ch data, so that processing time of 4 sec (denoted by a dotted line) represents the border for real-time processing for 1 ch data. We can see that the fastest one exceeds processing speed of 10 Mbps.

We have already processed 24-hour session data by using the software correlator, and it was confirmed that geodetic results obtained by the software correlator gave well-coincide results with those obtained by the hardware correlator.

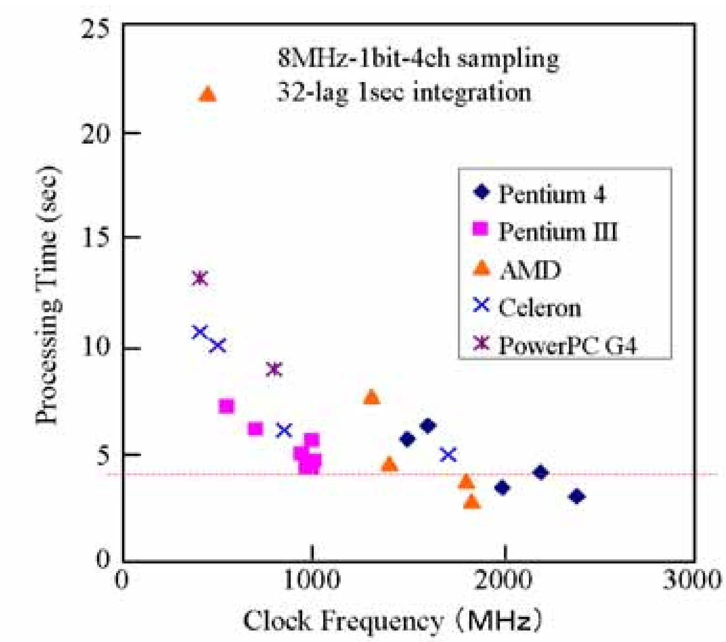

Figure 2. Benchmark test results of K5 geodetic software-correlator.

2.2. FX-type software correlator

We have also developed an FX-type software correlator specializing in processing speed to process gigabit VLBI system data mostly for an astronomical use [5]. In order to maximize the performance of CPU, various kinds of optimizations, such as an effective use of multi-processors and utilization of SIMD (Single Instruction Multiple Data) technology for parallel processing, were taken into the development. An assembler language program was also used partially to improve the performance.

Figure 3 shows results of performance test of the K5 FX software correlator using a PC equipped with dual AMD Athlon 1.8GHz processors. Throughput was measured for different lags, and reached about 90 Msps (it corresponds to the processing speed of 90 Mbps when 1 bit sampling are adopted) for lag numbers from 512 to 8192. The size of cash memory of CPU affected the performance at large number of lags, resulted in the performance loss. Multi-baseline correlations with multi-PCs are also planned to achieve further speed up of processing. By the use of the latest and fastest four PCs, it is possible to process 1Gbps data in real time.

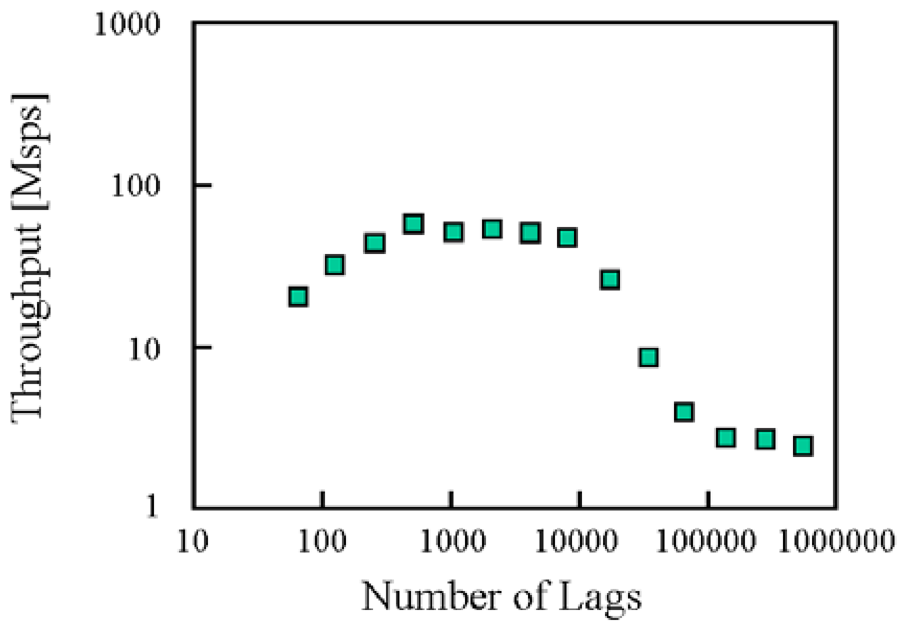

Figure 3. Performance evaluation results of K5 gigabit software-correlators.

3. Distributed correlation processing

We are developing a distributed processing system to increase total processing speed. Figure 4 shows one of ideas of distributed processing system to realize real-time processing using a number of PCs where each PC is incapable of real-time processing. Raw data are divided into a number of short-segmented data, e.g., 1 sec period data. A PC (leftmost PC in the figure) correlates the first pair of segmented data (labeled 00 in the figure). After this processing, the PC processes next available pair of segmented data (labeled 06 in the figure). Second (from the leftmost in the figure) PC first correlates the second pair of segmented data (labeled 01), and then correlates next available pair of segmented data (labeled 07). In this way the use of a number of PCs allows us to correlate raw data in real-time even though each PC has no capability of real-time processing. In order to realize this idea, we are developing a distributed processing system consisting of a server PC and client PCs like SETI@home. We named the system VLBI@home after SETI@home and are testing the system at our office (for details see the separate paper in this proceedings [6]).

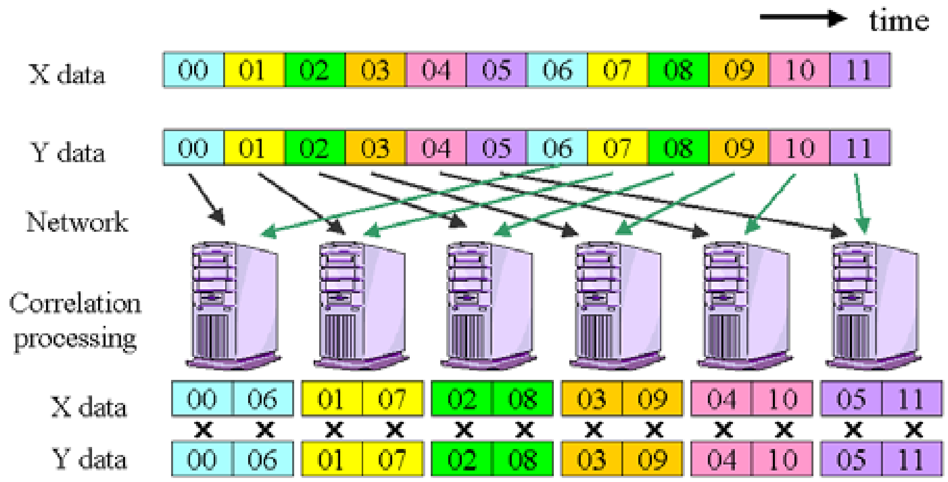

Figure 4. A principle of distributed correlation processing.

4. Conclusion

It is said that the performance of PC will improve double every two years and it will last at least about ten years from now. If it is true, we can expect the improvement of processing speed of a software correlator without any special improvement of software itself. Actually a software correlator run on a recent PC begins to have a practical processing speed to carry out routine correlation processing. A network-distributed processing system is also being developed to achieve further speedup. We think that a part of routine correlation processing carried out by a hardware correlator will be taken over by a software correlator in the future.

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