Software Correlators for Radio Astronomy

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The cross correlator is a fundamental tool of modern radio astronomy which converts time series of voltage measurements from a set of antennas and returns correlation coefficients which are used by astronomers for calibration of the antenna array and imaging the radio sky. In most cases the data volume is reduced by several orders of magnitude in this process and a majority of the computations required for the processing of the information for imaging is completed, making the task of the astronomer vastly simplified.

Historically, most radio astronomy correlators have been specially built analog or digital devices that derived their performance from highly optimized circuits. In most applications the use of a software correlator running on general purpose machines would have severely limited the performance of the radio interferometer. Today, software correlators for use in Very Long Baseline Interferometry (VLBI) are becoming increasingly practical as the computational cost is less than or comparable to that of the data transport from the very distant ($\sim 10^2$ to 10^4 km) antennas to a common data processing center.

A principle feature of software correlators is their extreme flexibility. Typically correlators are designed to maximum operating conditions, such as number of spectral channels per sub-band, integration time, or number of antennas. Exceeding design specifications on an existing correlator tends to require significant new hardware and engineering, if it is possible at all. On a software correlator changes of this type tend to be simple and likely don't require new hardware. Additionally, inclusion of special processing modes (such as pulsar gating or binning) does not require special hardware to be built.

In this talk, we will first discuss DiFX, a software correlator designed for processing VLBI data using off-the-shelf Linux-based workstations: its architecture will be described, its performance will be compared to existing VLBI correlators, and some results will be presented. Some generic features of software correlators, such as their flexibility, compatibility and expandability and examples of scientific applications that would benefit from software correlation will be discussed.