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Application of Parallel Processing - A Case Study on Weather Prediction

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***Abstract*— In this paper, we study about application of parallel processing on weather prediction. In particular, the predicted weather data about the future air state is essential and vital for all different areas of ecological modelling. Besides, the right choices to counteract harms and spare lives could be taken depending on a solid meteorological forecast process. Parallel processing takes a critical part in numerical climate and sea estimating models like Weather Research and Forecasting Model (WRF), Princeton Ocean Model (POM) and Regional Ocean Modelling System (ROMS). Numerical weather prediction is the most proficient intended to lessen the impact of startling climate occasions. Advances of high-performance computing have been enhanced much with the expanding of prediction accuracy and the time-critical requirement. There are existing operational centers like European Centre of Medium Range Weather Forecasting, UK (ECMWF) and National Centre for Environmental Prediction, USA (NCEP) which are exploring relationship between parallel processing and numerical weather prediction. This paper attempts to investigate and analyse the computational time required for the complex numerical simulations of climate and sea models using parallel processing.**

Keyword: parallel, numerical, weather, simulation, processors

I. Introduction

Numerical weather prediction is an application of numerical algorithm. It is utilized to anticipate the future condition of atmosphere by applying the initial state of weather. Numerical weather prediction has risen as one of the imperative controls requiring expanding computing power. State-of-art computers are utilized everywhere throughout the world to have exact timely forecasts [1]. Climate and weather modellers were among the main users who use parallel computers [2]. In parallel computing, distinctive parts of application code are figured in the meantime by various processors working in parallel.

Weather forecast contains complex mathematical models. To foresee the climate based on current climate conditions, numerical weather prediction utilizes mathematical models of the weather and oceans. Mathematical models based on the same physical standards can be utilized to create either short range weather forecasts or longer range weather forecast, the last are broadly connected for understanding and anticipating weather change. Different models use different mathematical solutions. In truth, numerical weather prediction models are dealt with soft-real time applications [3]. The significance of having a specific time is a real test for researchers. Hence, progressing research is focused on techniques to upgrade the advancement of expectation and to get conclusion of this progress.

Parallel computers can essentially accelerate climate forecasting. Fundamentally, the estimate is figured for little patches of the atmosphere in parallel. The computing time for a forecast is conversely proportional to the quantity of patches since the atmosphere can be tiled into smaller patches. It is considered that each patch can be dealt with by one processor of the parallel computer. Climate models have much fine-grained information parallelism, which was exploited by vector processors and the supercomputers of the 1990s [4]. Today, most register cycles for climate modelling originated from vast microprocessor-based bunches which cannot misuse parallelism significantly better than one sub domain. There are a few methods and mathematical models that are discussed in this paper according to the title given.

II. Historical background

The historical background of numerical weather prediction is considered on how ongoing weather state as contribution to mathematical models and oceans to foresee the future weather that has changed throughout the years. Then, parallel processing starts to be applied in numerical weather prediction to make it easier and efficient compared to sequential processing.

Generally, computer programming has been composed for sequential computation. An algorithm is developed and actualized as a sequential stream of directions to clarify the issue. Just a single guideline may be executed at once; after that direction is done, the following one is executed. Then, parallel processing started to develop. Parallel processing utilizes numerous computing components all the while to clarify the issues. The computing components can be various and incorporate assets like one computer with numerous processors, a few networked computers, specific equipment or any mix of the above stated.

The underlying foundations of numerical climate forecast can be followed back to the work of Vilhelm Bjerknes, a Norwegian physicist who has been known as father of present-day meteorology. In 1904, he distributed a paper proposing that it is conceivable to figure the climate by figuring out a system of nonlinear partial differential equations. The count took him a month and a half and the expectation ended up being totally implausible, however his endeavours were a look into eventual fate of climate prediction [5]. John von Neumann, the engineer of the first computer which is ENIAC, perceived that the issue of climate forecasting was common for his computing machinery. His group built a successful mathematical model of the climate and showed the practicality of numerical climate forecast in 1948 [6].

In 1950, at that point the USA National Service started to use a portion of the early forms of computers to make huge scale weather forecasts for running numerical weather prediction. Since that time, computers have turned out to be speedier and more complex by having the capacity to give researchers with High Performance Computing (HPC) stages. The stages allow the execution of exceedingly processing and requesting climate forecast simulations [7].

In 1965, vector and vector shared memory computer takes place. By offering the execution first in the tens, at that point hundreds and a great many megaflops, vector and vector shared memory computer have been utilized for the numerical simulations. The rising of computers control prompts better scales, elongated simulations and rising modernity in the modelling of weather progress. The parallel computers are more refined to give potential execution in the several gigaflops memory ability to permit issue sizes of beforehand recalcitrant measurements [8]. The parallel computers also demonstrated their part to give real-time forecasts of individual components of a serious tempest and multicentury simulations of atmosphere such as El Nino-Southern Oscillation (ENSO) and an unnatural weather change.

The extraordinary issue of parallel computing in climate and weather modelling is altered by John Drake and Ian Foster in year of 1965 [9]. It investigated the issues, which were identified with adjustment of worldwide models of the world's climate and seas to parallel computers. For a firmly related branch of geophysical applications such as regional scale models, the extraordinary issue was centred on the exceptional attributes, issues and implementation methodologies of parallel processing.

III. Methodology

A. *Parallel Multi-Level Genetic Ensemble for Numerical Weather Prediction Enhancement*

Other scheme that improves climate forecasts is called the parallel Multi-Level Genetic Ensemble or M-Level G-Ensemble. It utilizes a transformative algorithm (Multi Chromosome Genetic Algorithm) to enhance the estimation of conceivable physical parameters that will give more dependable expectations. The parallel M-Level G-Ensemble expectation plot demonstrated a critical change in forecast quality. This new plan is parallel and executed on a HPC situation keeping in mind the end goal to lessen the time expected to acquire the last forecast [10]. It means to enhance forecast quality by concentrating on the adjustment of information parameters and lessening complete execution time.

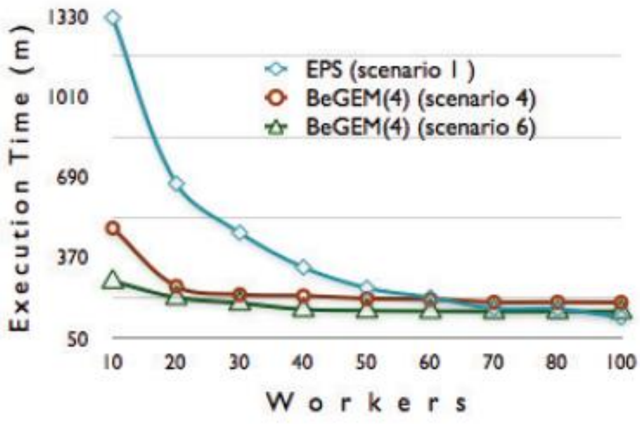

Fig. 1. The parallel version of M-Level G-Ensemble accomplished preferred execution times over Ensemble Prediction System (EPS) when both were executed on computing stages with a generally modest number of processors (under 50) [11]

B. *A Case Study of Large-Scale Parallel I/O Analysis and Optimization for Numerical Weather Prediction System*

Input/output (I/O) become barrier when going up to a huge number of processors for numerical weather prediction. Since that, the I/O access patterns of Global/Regional Assimilation and Prediction System (GRAPES) for numerical climate forecasts framework as an instance of customary multi-dimensional data access was examined. Two parallel I/O techniques were executed in view of MPI-IO and Adaptive I/O System (ADIOS), making full utilization of effective synchronous I/O plans. The idea behind MPI-IO is to give superior, compact, parallel I/O interface to elite, versatile, parallel MPI programs. MPI-IO documents are shared like various procedures running on different CPUs that can work on one MPI-IO that record all in the meantime. The record might be spread over the circle frameworks that have a place with those CPUs or it might be spread over some other parallel plate frameworks which can be obtained to by the CPUs over parallel correspondence channels. Analysis was carried out on the execution impacts of information design in the Luster document framework for MPI-IO. The "MPI_AMR" technique is applied to enhance the parallel yield transmission capacity which utilizes aggregator procedures to execute I/O operations and keep in touch with one sub file on one OST for every aggregator, diminishing I/O clashes for ADIOS.

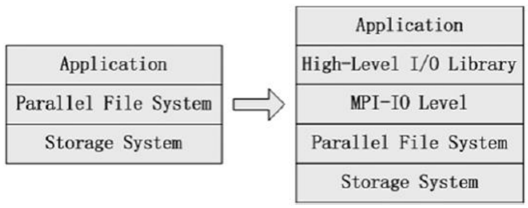

Fig. 2. The I/O stack [12]

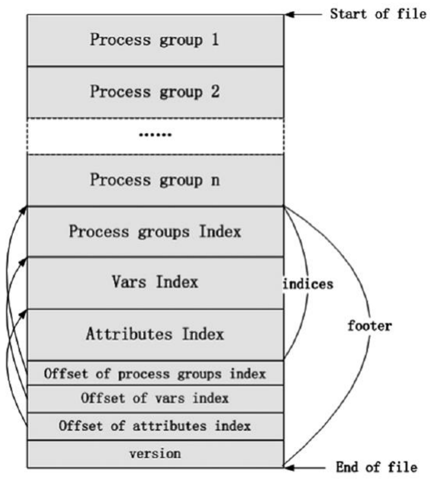

Fig. 3. ADIOS's Bp file format [12]

C. Role of Parallel Computing in Numerical Weather Forecasting Models

The present review is an endeavour to investigate and look at the computational time required for profoundly complex numerical simulations of climate and sea models with multi center processors and variable processor speeds. The simulations done utilizing machines of various computational capability which are quad center and Xeon machines have been explored with various engineered analyses in the operational estimating framework. The immersion rates with various numbers of processors are computed before completing prediction studies. Serial and parallel computations have been done with WRF (Weather Forecasting Model) model for re-enacting the track of a characteristic danger. Parallel processing simulations demonstrated that the model simulations rely on the model time step, grid resolution, number of cells in the space, framework design, and number of vertical levels and their resolutions. The regional models are utilized as partner to global models, having various essential basic and algorithmic contrasts that bear on their appropriateness of parallel computers. Regional model are more straightforward than global models in numerical methods by applying finite difference methods without unique treatment required around a pole [13]. Moreover, the utilization of finite difference methods has ideal implications for parallelization since such strategies are closest neighbour and along these lines more direct to actualize proficiently than the spectral strategy utilized in some global models.

D. Benchmarking of Medium Range Weather Forecasting Model on PARAM - A Parallel Machine

Department of Science and Technology, Government of India started the investigation of cost-effective computing solution to the climate prediction models in order to contribute in this new research try in parallel processing. A noteworthy stride was taken to measure the enlistment of parallel processing in the Indian setting. Subsequently a venture to port and parallelism the global prediction model T80L18 of National Center for Medium Range Weather Forecasting, New Delhi, India (NCMRWF) was begun with Centre for Development of Advanced Computing, Pune, India [14]. The execution of medium range climate prediction code T80 was defined on a distributed memory parallel machine – PARAM [15]. The prime target is to investigate the parallelism for the spectral strategy in T80 code and to test its execution. It is shown that the performance of parallel T80 for one day estimate beats the slipped by time for the same on CRAY XMP/216 at NCMRWF. Up gradation of Indian prediction model to better determination codes such as T213L31 or T126L28 on the C-DAC's parallel machine with the total arrangement comprising of decoder, examination, figure and post-handling is proposed.

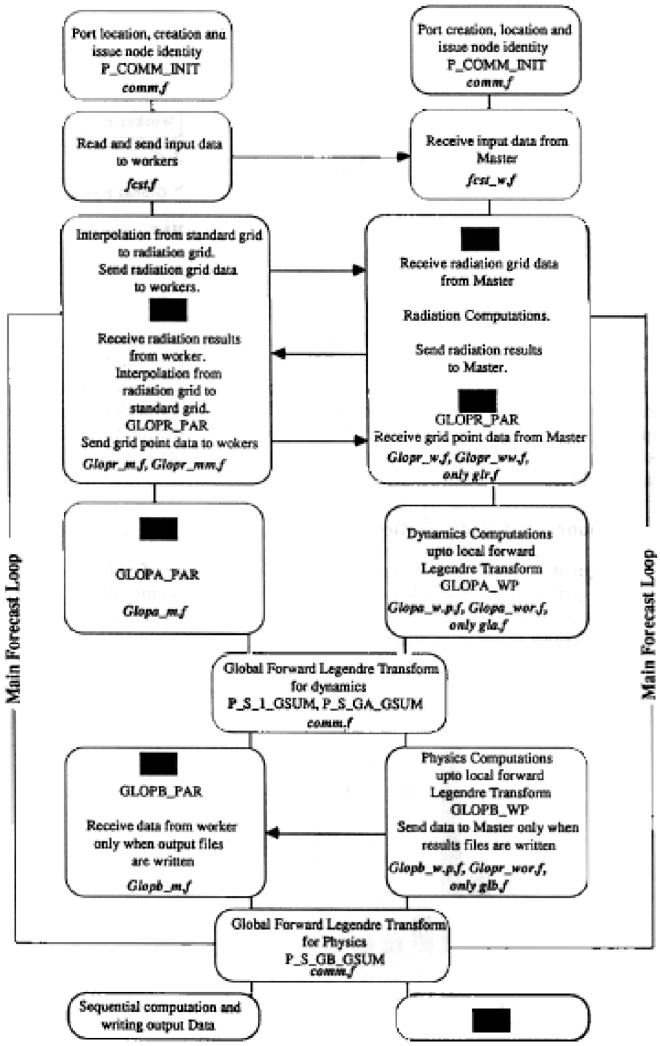

Fig. 4. Parallel T8O flowchart [14]

E. Parallel Computing for Weather Prediction

NWP models can not completely resolve climate happening on the size of their grid lengths. Topographic impacts should likewise be smoothed. Therefore, models sift through impacts on scales beneath around 5 lattice lengths. On the off chance that this is not done, at that point computational noise will overwhelm the meteorological flag. Finer resolutions of the climate models would permit more solid and more exact figures [16]. Be that as it may, they request basically more prominent computer control, which can be given just by parallel systems. Integrated Forecasting System (IFS) generation code, that is utilized every day for the European climate expectation, can now be kept running in on real parallel system.

IV. Conclusion

The study clarifies the varieties in the model simulation time in the sequential mode and parallel mode. The model simulations have taken longer time in sequential mode and less time in the parallel mode. In conclusion, it is clearly shown that the parallel processing takes an important role in determining the prediction of weather. The outcomes affirm that the parallel calculations are extremely useful for making fast simulation with increasing number of processors for brisk and compelling climate prediction. These studies also prove that there are many mathematical models that can be applied in weather prediction. The suitability of the models depends on the research itself. In future, hopefully there will be many researchers who will continue this study about application of parallel processing on weather prediction.

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