EAPoster: Designing Parallel - Incorporating PDC Concepts in the course of Algorithms

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***Abstract*—Parallel Computing provides significant building block for many technological advancements. In order to teach parallel computing effectively, it is essential that students' design and analysis abilities be improved. This paper describes our efforts for incorporation of parallel computing curriculum in the course of Algorithm Analysis and Design. The objective of introducing parallel computing topics is to strengthen designing of parallel algorithms, which would help them in developing parallel programs. This paper describes pedagogical goals of the integration plan and demonstrate results of students evaluation.**

Keywords-component; Computer Science Education, Parallel Computing Education, Distributed Computing Education, CS Curriculum, Algorithm Analysis and Design

I. INTRODUCTION AND MOTIVATION

Parallel and Distributed Computing (PDC) provides foundation for many technological advancements. In this context, it is pertinent that PDC concepts are taught effectively to students in order to enhance their learning. Significance of PDC curriculum at the undergraduate level has been highlighted through the efforts of IEEE TCPP [1]. The focus of this paper is to describe incorporation plan of PDC topics in the course of Algorithm Analysis and Design.

There are a few important aspects which highlight the significance of Algorithms course for PDC topics. First and foremost, the course develops and enhances students thinking and designing capabilities. Imparting parallel topics through this course, is likely to provide a meaningful impact to students' learning. Further, teaching parallel algorithm design skills is likely to benefit students in many subsequent courses where application of parallel programming is incorporated [2].

Motivated by these two considerations, this paper describes incorporation plan of parallel computing topics in the course of design and analysis of algorithms. The paper presents the details of the plan describe results of sttudents evaluation. The adaptation plan has been supported through early adapter award fall 2013 [3].

II. PEDAGOGICAL GOALS AND CURRICULUM ADAPTATOIN

This section highlights main objectives of curriculum integration plan and describes methodology for integration at National University (NUCES), Karachi Campus. The university is the pioneer of Computer Science education in Pakistan. It has campuses in five different cities of the country.

Table 1 - Pedagogical Goals

Goals	Description
G1	Impart necessary background knowledge about parallelism
G2	Strengthen design and analysis skills for parallel algorithms
G3	Prepare students for PDC programming

A. Pedagogical Goals

The main objective of our integration plan is to strengthen parallel algorithm design techniques. This objective is composed of three important goals (Table 1):

G1: Background knowledge about PDC topics is essential. This include many fundamental topics such as motivation for PDC, need for parallelism, what are the fundamental requirements of parallelizing a task, what are the benefits of parallelism, why there is a need for distributed computing, what is speedup, etc. It is anticipated that all such questions must be properly clarified in order to increase student's comprehension and enhance their motivation.

G2: The second goal of our curriculum plan is to build upon background knowledge to strengthen parallel program design. These include identifying dependencies, maintaining exclusion for shared memory access, and appropriate task division among worker threads and processes.

G3: The third goal of the plan is to impart implementation and programming skills. For instance, utilization for memoization for dynamic programming; using spawn and sync for threads creation and synchronization, and incorporating divide and conquer strategies for various parallel algorithms. The course also covers analyzing performance gain through speedup.

B. Adaptation

The algorithms course is in part focused on strengthening designing and analysis skills. Table 2 describes the details of the parallel topics covered in the course. These topics were introduced through code analysis and writing pseudo code of parallel algorithms. Students were demonstrated

Table 2- PDC Topics

Topics	What was covered/ How it was covered	Alignment with Goals
Parallel Algorithm Design	Asymptotic Analysis. Work done and Time Complexity	G1 and G2
Sync and Spawn	Thread synchronization in parallel algorithms	G2, and G3
Fibonacci	Parallel version with memoization	G2 and G3
Parallel Loops	Parallel for loops	G2 and G3
Merge Sort	Divide and Conquer with parallel merge	G2 and G3

advantage of parallelism through speedup. Specifically, speedup was demonstrated for Fibonacci series, matrix multiplication, and merge sort (including parallel merge).

III. EVALUATION

For PDC topics, two evaluations were conducted:

1) A specific quiz was taken to assess students' comprehension on simple parallel algorithms. The quiz asked the students to compute all pairs shortest path in a graph using parallel strategy. This could be solved by spawning multiple instances of Dijkstra's shortest path algorithm.

2) Later, during the final exam, the students were asked to parallelize a divide and conquer algorithm and compute speedup. Both the evaluations were focused on designing and analyzing algorithms. Following are the key observations during our evaluations:

- Evaluation results in the PDC topics (average = 50%) was lower than the overall evaluations in the course (61%). This shows that designing parallel algorithms is a competitive topic. It requires more efforts.
- Evaluation results of the PDC topics in the final exam (average = 51 %) was better than the evaluation results in the quiz (Average =29%). This is probably due to the fact that the students were better prepared for the final exams.

It was also observed that for PDC topics, students performed better in Divide and conquer algorithms. This is due to the fact that the topic is easier in visualization and comprehension.

IV. LESSONS LEARNED, AND FUTURE WORK

The paper presents details of the curriculum integration plan, which is focused on incorporating PDC topics in the algorithms analysis and design course. Overall, the incorporation plan has been successful as students have demonstrated improved learning throughout the course. Following are important lessons learned from the course.

- During the course, it was observed that for PDC topics which were covered through visualization and programming (such as divide and conquer), students demonstrated improved learning.
- For parallel topics, it is essential that the corresponding serial topic is covered comprehensively. During the quiz evaluation relevant to parallel algorithm design, students secured lower marks. This may be due to incomprehensive understanding of students in the relevant serial topic.

For future, the plan is to further strengthen the course of Algorithms. In the current adaption, parallel topics were introduced during the 15th week of the semester. This may have resulted in weaker comprehension of the topic. The proposed plan is to revise the course by introducing parallel topics during the 13th week. Earlier introduction of these topics is likely to yield increased comprehension of students. It is also plan to give a programming assignment on parallel programming. This will lead to enhanced learning for students.

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BUDGET

Item	Estimated Cost in USD
Return Flight from Karachi, Pakistan to Chicago, USA	1000 USD
Registration Fee	600 USD
Hotel/Lodging for 5 nights	1000 USD
Meals / Transport	200 USD
Total	2800 USD

REFERENCES

[1] NSF TCPP Curriculum Initiative http://www.cs.gsu.edu/~tcpp/curriculum/?q=home

[2] Jawwad A. Shamsi, Nouman M. Durrani, and Nadeem Kafi. "Novelties in Teaching High Performance Computing." In *Parallel and Distributed Processing Symposium Workshop (IPDPSW), 2015 IEEE International*, pp. 772-778. IEEE, 2015.

[3] Integrating PDC Topics in core courses of BS (CS) at FAST-NU