



Assessing the Integration of Parallel and Distributed Computing in Early Undergraduate Computer Science Curriculum using Unplugged Activities

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Outline

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Introduction

❖ Motivation

- Pervasiveness of parallel and distributed computing (PDC) in science and engineering domains
- ACM/IEEE joint curriculum recommendations
- NSF CDER early adopters workshop in July 2018 and June 2019
 - PDC incorporation via unplugged activities in CS 0, CS 1, & CS 2 courses
- Student engagement - an under explored domain in PDC education

❖ Challenges

- Researchers have different levels of PDC knowledge
 - Ranging from an expert to basic level of understanding
- Collaborative research across four different universities
 - Varying time zones, limited to virtual meetings
 - To provide a proof of concept, analysis has been limited to single group post test
- Limited existing resources for PDC based unplugged activities



Introduction

❖ Key Novel Contributions

- Employing an active learning based PDC teaching module that consists of a set of two unplugged PDC activities for introducing PDC concepts in existing undergraduate level CS courses at four universities.
- Using ASPECT, a pre-validated survey tool, for measuring student engagement towards the incorporated PDC modules in existing CS courses at four different universities.
- Using statistical analysis to study the impact of age, gender, and class standing (freshman, sophomore, junior, or senior) on student engagement towards the active learning PDC modules.



Background and Related Work

❖ PDC

- Envelopes distributed systems, parallel computational hardware, parallel applications and programming, high performance computing, and others
- Recommended by ACM/IEEE curriculum report to be included as a core topic in CS undergraduate education
- NSF CDER initiative
 - Outlining important PDC topics
 - Conducting training workshops for educators
 - Designing standard textbooks for PDC

❖ Existing research

- Promotes parallel structure for processing information
- Points to lack of PDC knowledge in recent CS graduates leading current workforce
- Outlines educational interest and need for PDC in undergraduate CS curriculum
- Provides a limited set of instructional resources/tools for incorporating PDC into existing undergraduate CS curriculum
 - Gap in literature: understanding and measuring student interests and learning PDC topics



Research Plan and Design

- ❖ Determining Relevant Courses
 - Identify commonality in courses taught at the four universities
 - Categorize the identified courses into CS0, CS1, and CS2 levels
 - Maintaining the focus of NSF CDER Summer training Program from June 2018
 - Identify a set of PDC based unplugged activities to be implemented uniformly across each university
 - Facilitating analysis of utility and generality of the teaching modules
- ❖ Selected Courses
 - CS0 level courses
 - CMSC 105-01: Elementary Programming, and CSE 1002: Introduction to Computer Science and Software Engineering,
 - CS1 level course
 - CSCI 2911: Computer Science I,
 - CS2 level courses
 - CSCI 2912: Computer Science II, and CS 311: Data Structures and Analysis of Algorithms,
 - CS3 level course
 - CMSC 395: Digital Image Processing.



Research Plan and Design

- ❖ Creating the active learning teaching modules
 - Designing two unplugged activities
 - Description and implementation plan
 - Incorporating student engagement survey (based on ASPECT) including demographic data
- ❖ Unplugged Activities
 - More Processors are Not Always the Best (MP)
 - Penny Sorting Exercise (PE)



Research Plan and Design

Active Learning Module 1

- ❖ Collect consent forms (as required by your IRB)
- ❖ Implement MP activity in class (described on the next slides)
- ❖ Have a follow up class discussion on the PDC topics introduced
- ❖ Have participants complete the student engagement survey

Research Plan and Design

Activity Description

MORE PROCESSORS ARE NOT ALWAYS THE BEST

UNPLUGGED ACTIVITY DESCRIPTION

The activity involves participation of two or more students for the following phases:

Uniprocessor Sequential phase

Participant 1 - acts as a processor to perform

Participant 2 - times the tasks performed by participant 1.

Task 1: writing a sentence (*more processors are not always the best*), followed by

Task 2: assigning a numeric value as an index (*0,1,...32*) to each character in the written sentence.

UNPLUGGED ACTIVITY DESCRIPTION CONT'D...

An example of the two writing tasks:

M	o	r	e	P	r	o	c	e	s	s	o	r	s	A	r	e	N	o	t	A	l	w	a	y	s	T	h	e	B	e	s	t	
0	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3
										0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	

The above two tasks can be timed either in serial or in parallel in one of the activity phases.

UNPLUGGED ACTIVITY DESCRIPTION CONT'D...

Uniprocessor Multi Tasking Phase

Participant 1 - acts as a processor to perform

Task 1: writing a sentence (*more processors are not always the best*), interleaved character by character with

Task 2: assigning a numeric value as an index (**0,1,...32**) to each character in the written sentence, interleaved with Task 1, number by number

Participant 2 - times the tasks performed by participant 1.

Compares performance with Sequential Phase

UNPLUGGED ACTIVITY DESCRIPTION CONT'D...

Two Processor Parallel Phase

Participant 1 - acts as a parallel processor to perform

Task 1: writing a sentence (*more processors are not always the best*)

Participant 2 - acts as a parallel processor to perform

Task 2: assigning a numeric value as an index (0,1,...32) to each character in the written sentence.

Participant 3 - times the tasks performed by parallel participants 1 and 2.

Compares performance with Sequential Phase and multi-tasking phase

UNPLUGGED ACTIVITY DESCRIPTION CONT'D...

Multi Processor Parallel Phase

Participant 1 -

|(Task 1)/2|: writing a partial sentence (*more processors are*)

Participant 4 -

|(Task 2)/2|: assigning a numeric value as an index (*continues from participant 3*) to each character in the partial sentence written by participant 2.

Overhead: may have to wait on participant 3 to continue proper indexing.

Participant 2 -

|(Task 1)/2|: writing a partial sentence (*not always the best*)

Participant 3 -

|(Task 2)/2|: assigning a numeric value as an index (*starting at 0*) to each character in the partial sentence written by participant 1.

Participant 5 - times the tasks performed by parallel participants.

Compares performance with Sequential Phase and multi-tasking phase and previous parallel scenario.

AMDAHL'S LAW LIMITATIONS: SCENARIO ON PREVIOUS SLIDE

A SUGGESTED IMPROVEMENT - INCREASE # OF TASKS

Participant 1 -

| (Task 1)/2 |: writing a partial sentence (more processors are not always the best)

Participant 4 -

Task 3: calculating the total number of characters for each word in the sentence

Participant 2 -

| (Task 1)/2 |: writing a partial sentence (more processors are not always the best)

Participant 3 -

Task 2: assigning a numeric value as an index to each character in the sentence written by participants 1 and 2.

Participant 5 - times the tasks performed by parallel participants.

Compares performance with Sequential Phase and multi-tasking phase and previous parallel scenario



Research Plan and Design

Active Learning Module 2

- ❖ Collect consent forms (as required by your IRB)
- ❖ Implement PE activity in class (described on the next slides)
- ❖ Have a follow up class discussion on the PDC topics introduced
- ❖ Have participants complete the student engagement survey

Research Plan and Design

Activity Description



PENNY SORTING EXERCISE

ACKNOWLEDGEMENT: BRETT DECKER

UNPLUGGED ACTIVITY DESCRIPTION

I have say 20 or more (depending on the size of your class) coins and the problem is to find the oldest one in the quickest time. So we are going to do it first in a sequential mode and then in various parallel variations.

Have students break into groups of 3 (or more depending on the size of your class).

Phase 1 (sequential): each group (3 participants, student 1 sorting and student 2 timing, student 3 observing)

Teacher gives one student from each group 20 pennies, have that student find the oldest penny while the second student times it and writes it down on a piece of paper The third will observe.

Shuffle coins

UNPLUGGED ACTIVITY DESCRIPTION CONTD....

Phase 2 (Parallelize it): each group (students 1 and 2 are given equal number of pennies and are asked to find the oldest penny in their pile, student 3 records the times for student 1 & 2)

Teacher gives student 1 & 2 of each group an equal number of pennies. At a set time, sorting begins for all groups. Student 3 records the time it takes each student to find the oldest penny in their pile.

Shuffle coins

UNPLUGGED ACTIVITY DESCRIPTION CONTD....

Phase 3 (Parallelize it-2): each group (students 1 and 2 are given 3 pennies each and student 3 is given the rest of the pennies and are asked to find the oldest penny in their pile, student 4 records the times for student 1, 2, and 3)

This is poor load balancing!

Shuffle



Research and Analysis

Demographic Factors			
Student Engagement Constructs	Gender (Male/Female)	Age (18-22, 23-27, 28-32, 33-over)	Class Standing (Freshman, Sophomore, Junior, Senior)
Value of Activity	MP - No difference PE - No difference	MP - No difference PE - Difference*	MP - Difference* PE - No difference
Instructor Contribution	MP - No difference PE - No difference	MP - No difference PE - Difference*	MP - Difference* PE - No difference
Personal Effort	MP - No difference PE - No difference	MP - No difference PE - No difference	MP - No difference PE - No difference
Activities: MP PE			
*Statistical significant difference			



Conclusions

- Further studies are underway to evaluate the impact of demographic factors on the student engagement constructs with larger data set for a more in-depth and sound statistical analysis
- The authors plan
 - to continue developing additional unplugged and programming-based teaching modules to introduce PDC topics in existing undergraduate CS courses at their respective universities
 - to include more qualitative data analysis with a larger sample and add other measures (such as instructor and student expectation) for a broader assessment of student engagement
 - to extend the analysis to pre-test post-test analysis while evaluating student learning



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Questions?

Thank you for listening

