TCPP Curriculum Initiative: Integrating Parallel and Distributed Computing in Early Computing Classes

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R. Vaidyanathan, LSU

EduPar-24, May 27, San Francisco
https://tcpp.cs.gsu.edu/curriculum/

Public Feedback on TCPP Curriculum & Contact
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IEEE Computer Society TCPP
Sponsors Intel & NVIDIA
NSF

QR Codes for Additional Information
TCPP Curriculum Initiative
What should every Computer Science and Engineering Student know about Parallel and Distributed Computing (PDC)?
https://tcpp.cs.gsu.edu/curriculum/

• **Areas**: Programming, Architecture, & Algorithms
  • Version 1 – 2012

• **New Aspects**: Big Data, Energy, Distributed Computing, Pervasive topics
  • Version-2-beta released 2020
  • URL

• **Companion Activities**: 
  • CE-oriented TCPP Curriculum
  • NSF Project on CS1/CS2 Exemplars
    • Recruiting Testing teams
    • Apply by March 31st: URL
Some Participants at the NSF Planning Workshop
Washington DC, Feb 5-6, 2010

Main Outcomes

- Priority: Core curriculum revision at undergraduate level
- Preliminary Core Curriculum Topics
- Sample Intro and Advanced Course Curriculums
CDER - Center for Parallel and Distributed Computing Curriculum Development and Education Resources - Timeline

- NSF Planning Workshop
- TCPP Curriculum v1
- NSF CI-ADDO $1.2 M
- ACM/IEEE CS2013 Curricula
- JPDC Special Issue
- CDER Book Vol. 2
- JPDC Special Issue
- TCPP Curriculum v2-beta

- 2010
- 2011
- 2012
- 2013
- 2015
- 2017
- 2018
- 2019
- 2020

- EduPar @ IPDPS
- EduHPC @ SC
- Early Adopter Competitions (Intel/Nvidia for International) – 143 Early Adopters
- EuroEduPar @ EuroPar
- CDER Book Vol. 1
- EduHiPC @ HiPC, India
- CyberTraining Implementation (2020-23) $1M
- CyberTraining Workshops
### 3 Curriculum Areas + Cross-Cutting
Architectures, Programming, Algorithms

#### TCPP Curriculum Example

<table>
<thead>
<tr>
<th>Algorithms Topics</th>
<th>Bloom#</th>
<th>Course</th>
<th>Learning outcome and teaching notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithmic problems</td>
<td></td>
<td></td>
<td>Algorithmic problems section contains parallel algorithms for certain problems. The important thing here is to emphasize the parallel/distributed aspects of the topic</td>
</tr>
<tr>
<td><strong>Communication and Synchronization</strong></td>
<td></td>
<td></td>
<td>Understand (at the pseudo-code level) how certain patterns of communication can be implemented in a parallel/distributed model. Also appreciate the cost of communication in PDC.</td>
</tr>
<tr>
<td>Reduction and Broadcast for communication and synchronization</td>
<td>C</td>
<td>Data Struc/Algo</td>
<td>Understand, for example, how recursive doubling can be used to for all-to-one reduction, and its dual, one-to-all reduction, in $\log(p)$ steps. The same applies to all-to-all broadcast and all-to-all reduction. Recognize that all-to-all broadcast/reduction are synchronizing operations in a distributed (event-driven) environment.</td>
</tr>
<tr>
<td>Parallel Prefix (Scan)</td>
<td>C</td>
<td>Data Struc/Algo</td>
<td>Understand the structure of at least one simple parallel prefix algorithm. One could consider recursive or iterative approaches (such as those of Ladner-Fischer, Kogge-Stone, Brent-Kung)</td>
</tr>
<tr>
<td>Multicast</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permutation</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Early Adopter and Training Programs

• Over 200 early adopter and trainee institutions worldwide
  – Spring-11: 16 institutions; Fall’11: 18;
  – Spring-12: 21; Fall-12: 25 institutions, Fall-13: 25 institutions, Fall-14: 25, Fall-15: 13
  – Most from US (4 year to research institutions, one high school)
  – Some from South America, a few from Europe, fewer from Asia (India, China, Indonesia, Singapore), Middle East

• NSF CyberTraining Workshops – Weeklong in Summer 2018-24
  – UMass, LSU; UMass/Maryland; Tennessee Tech
  – NSF funded stipend up to $5K/proposal
  – Instructor training + adoption plans

– Additional Training workshops
  - SIGCSE 2023, 2024
  - HiPC 2022, 2023, 2024
Edu* Workshop Series

- **EduPar-11** at IPDPS-2011
  - Receive feedback from the Adopters
  - Stimulate discussion of curricular and other educational issues.
- **EduPar-12** at Shanghai, IPDPS-2012
  - A regular satellite workshop of IPDPS
- **EduHPC at SC-13** + BOF at SIGCSE-14
- **EduHiPC 2018 @ HiPC**– for India and the region
  - EduHiPC’19 Hyderabad, EduHiPC’21 – online, EduHiPC’22, EduHiPC’23 in Goa, **EduHiPC’24 in Bangalore**
Additional CDER Resources

- **CDER Book series:**
  - **Vol 1:** Topics in Parallel and Distributed Computing
    - Introducing Concurrency in Undergraduate Courses, *Morgan Kaufman*
  - **Vol 2:** Topics in Parallel and Distributed Computing
    - Enhancing the Undergraduate Curriculum: Performance, Concurrency, and Programming on Modern Platforms, *Springer*
  - **Free Pre-Print Version** on CDER site *(50K+ downloads)*
  - **Plan for 3rd and 4th Volume** – Experience of Adopters; Version 2 topics
    - Exemplars + Resources on courses and topics
  - **JPDC Special Issue** - Keeping up with Technology: Teaching Parallel, Distributed and High-Performance Computing (2017, 19, 21)
    - **CFP** - Paper Submission deadline: May 31, 2024, [URL]
CDER Courseware Website

Upload and Search Course Material

- **Type:**
  - Slides, Syllabus, Tutorial, Video
  - Animation, Article, Award, Blog, Book, Competition
  - Course Template, Course Module, Data
  - Hardware Access, Software/Tools
  - Proposal, Report

- **Courses:**
  - CS1, CS2, Systems, Data Structures and Algorithms, ...

- **NSF/TCPP Topic/Subtopic Classification:**

  ALGORITHMS
  - Parallel and Distributed Models and Complexity
  - Algorithmic Paradigms
    - Divide & conquer (parallel aspects)
  - Algorithmic problems

  ARCHITECTURE

  PROGRAMMING

  CROSS-CUTTING

- **open** - Work in Progress

EduPar'24
## Curriculum Version II Activities

<table>
<thead>
<tr>
<th>New Aspects</th>
<th>Areas</th>
<th>Architecture</th>
<th>Algorithms</th>
<th>Programming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Lead/Aspect Lead</td>
<td>Chip Weems</td>
<td>Anshul Gupta</td>
<td>Alan Sussman</td>
<td></td>
</tr>
<tr>
<td>Exemplars</td>
<td>Sushil Prasad</td>
<td>Karen Karavanic, Eric Freudenthal</td>
<td>Erik Saule, Duane Merril, David Bunde</td>
<td>David Brown, Eric Freudenthal</td>
</tr>
<tr>
<td>Distributed</td>
<td>Vaidyanathan Ramachandran</td>
<td>Vaidyanathan Ramachandran, Manish Parashar</td>
<td>Vaidyanathan Ramachandran, Costas Busch, Denis Trystram</td>
<td>Alan Sussman, Chi Shen</td>
</tr>
<tr>
<td>Big Data</td>
<td>Trilce Estrada</td>
<td>Craig Stunkel</td>
<td>Cynthia Phillips</td>
<td>Debzani Deb</td>
</tr>
<tr>
<td>Energy</td>
<td>Krishna Kant, Craig Stunkel</td>
<td>Craig Stunkel, Karen Karavanic</td>
<td>Denis Trystram</td>
<td>John Dougherty</td>
</tr>
<tr>
<td>Pervasive</td>
<td>Sheikh Ghafoor</td>
<td>Craig Stunkel, Eric Freudenthal</td>
<td>Robert Robey, Martina Barnas</td>
<td>Sheikh Ghafoor, Eric Freudenthal</td>
</tr>
</tbody>
</table>
• **Timeline:**
  
  - **Version-2-beta released** @ EduHPC’20
    - Public Feedback: sushil.prasad@gmail.com
  
  • **Companion Activities:**
    - CE-oriented TCPP Curriculum
    - NSF Project on CS1/CS2 Exemplars Development (Oct 23-26)
      - Recruiting Testing teams
      - Apply by March 31st: [URL](#)
  
  • NSF Institute Planning Grant =&gt; 5 planning workshops
    1. **SC’19, SIGCSE’20, July’20, & Mar’21** - online
    2. **NSF Reporting Workshop** – Oct’21 - [See Final Report](#)
Computer Engineering Curriculum

• Current Status
  • PDC Principles
    • Concurrency, Asynchrony and Locality
    • Decomposition and Coordination
    • Performance and Pitfalls
  • CE Courses
    • Intro, Math, Logic, Circuits, Programming, Signals and Communication, Networks, Embedded Systems, Organization and Architecture, OS, CPS, ML
  • Broad areas
    • Hardware and Architecture
    • Programming and Algorithms
    • Communications and Systems
  • PDC intro ideas

• In Progress
  • Subcommittees in each broad area
  • Within broad areas, mapping topics to courses

• In the future
  • Mapping topics to PDC principles
  • Curriculum Guideline

We need your help