Integrating Parallel Computing courses into the Undergraduate Programs in ICT and Computational Science

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Introduction

- **DA-IICT, India** offers two undergraduate programs (4 years/8 semesters): B.Tech (ICT) – 260 students/year, and B.Tech (Honours in ICT with minor in Computational Science) – 60 students/year.
- **Goal**: to integrate PDC topics into several core and elective courses throughout the DA-IICT undergraduate program (3rd year/semester-V onward).
- **ICT** = Computer Science + Electronics and Communication + Information Technology.
- Background of Students: programming, discrete mathematics, computer organization, algebraic & data structures, systems software, communication, electronics, algorithms etc. (first 2 years).

Course Design and Implementation

- **Objective**: to provide practical exposure and hands on development experience.
- Strengthen the student’s development, design and analytical skills.
- **Two new courses introduced**: Introduction to GPU Programming (IT477) for B.Tech (ICT) in 2014. High Performance Computing (CS301) for B.Tech (Hons. in ICT with minor in CS) in 2015. Module driven approach. Total five modules, each module consisting of about 6-7 lectures.
- Focus on case studies, assignments and team projects. (domains of CS and ICT)
- A schematic of the strategy adopted in designing the courses is given below.

Courses/ Theory

**CS301 (core course, semester V)**
- Batch size: 60 CS students.
- 3 hrs. of lectures and 3 hrs. of lab/week
- Platforms: OpenMP, MPI.
- Bloom: primarily K and C; scope of A.

**IT477 (elective course, semester VII)**
- ICT students, PG students
- 3 hrs. of lectures and 2 hrs. of lab/week
- Platform: CUDA C.
- Bloom: primarily K and C; scope of A.

Computational Lab for HPC

- Accommodation: 60 students (CS301)
- Desktops: 30 (each equipped with Quad core high-end Intel processor and NVIDIA GPUs.)
  - **GPU lab**: 4 workstations (Each has 16 CPU cores Xeon processors, Tesla K-40 GPU card).
  - **HPC Heterogeneous (CPU+GPU) Cluster**: 5 nodes (total 80 CPU cores, .4 TB RAM, 25 TB HDD, InfiniBand interconnect, Tesla K40 GPUs).
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Evaluation

- **Continuous student evaluations** through quizzes, exams, assignments, projects & class presentations. Helps in assessing the teaching methodology.
- **Compulsory lab assignments** (~ 6-7).
- **Compulsory 1 month Team Project** to drive student interest in research related applications.
- Student evaluation - based on 2 mid-semester exams (60%), and lab assignments & final project (40%).
- Subjective assessment (teaching methodology) : survey/student feedback with 14 questions.
- Motivate students for advanced topics and participation in HPC student contests.

Assignments

Compulsory report on the following aspects / observations for each assignment:

- **Context:** Brief description of the problem.
  Complexity of the algorithm (serial).
  Possible speedup (theoretical).
  Profiling information (e.g. gprof).
- **Parallelization/ Optimization strategy.**
- **Problems faced in parallelization and solutions.**
- **Hardware details:** CPU model, memory, compiler.
- **Input parameters. Output.** Comparison of results from serial and parallel code.
- **Problem Size vs Time** (Serial, parallel) curve.
- **Speedup curve. No. of cores vs. speedup curve for a couple of problem sizes.**
- **Observations and comments about the results.**
- **Measure performance in MFLOPS/sec.**
- **If more than one implementation, curves for all algorithms in the same plot.**

Sample Team Projects

- Parallelization of Heat Diffusion Problem
- Parallelize the Merge Sort and Quick sort
- Parallelization of Gauss Elimination Method
- Parallel implementation Traffic Flow Modeling using Cellular Automata
- Parallel String Matching : Naive and Rabin Karp algorithms
- Sierpinski Hexagon and Sierpinski carpet Fractal
- Mandelbrot Set: Fractals
- Edge Detection in Images, Canny Edge Detector
- Parallel Dijkstra's algorithm
- Parallelization of AES Encryption Algorithm using OpenMP
- Parallelized Kruskal's Algorithm
- Crowd Dynamics and Travelling Salesman Problem – parallel and serial implementation.
- Parallel implementation of Histogram Equalization

Outcome and Future Work

- This integration encouraged the students to undertake **BTP projects** (a compulsory 4 month B.Tech project in the final semester for the award of the B.Tech degree) in the **domain of HPC**.
- A student team from DA-IICT who took the HPC course (CS301) was awarded the **third prize in Student Parallel Programming Challenge** supported by **Intel and nVIDIA** at IEEE HiPC 2015, Bangalore, India. Algorithm: Parallel High Dimensional Data Clustering.
- The author believes that delivering the lectures in a **structured manner** and **focusing more on actual lab implementation** encourages better student learning. Looking at the positive outcome, new courses in this direction are being planned and will likely follow.

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