ACM/IEEE-CS/AAAI
COMPUTER SCIENCE CURRICULA (CS2023)

PANEL WEAC - Workshop on Computer Architecture
Education @SBC WSCAD 2022

Marcelo Pias
FURG
CS2023 SC Member

Cristian Koliver (UFSC)
Carlos Augusto Martins (PUC Minas)
CS2023 Panel: Plan

- Introduction to the CS2023 curricula [30 min]
- Computer Architecture Education in Brazil [10 min]
  - Carlos Augusto Martins (PUC Minas)
- Education and Curriculum Perspective in Brazil [10min]
  - Cristian Koliver (UFSC)
- Panel Questions and Discussion [20 min]
Version Alpha

- Posted on csed.acm.org
  - Email, form for each KA
  - Posted to 12+ SIGs, country mailing lists in May
    - Quarterly outreach
- Undergoing reviews
CS2023 Architecture and Organization (AR KA)
October 2022 Overview and Status

https://csed.acm.org/architecture-and-organization/
### CS Core vs KA Core

<table>
<thead>
<tr>
<th>Knowledge Unit</th>
<th>CS Core</th>
<th>KA Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR/Digital Logic and Digital Systems</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>AR/Machine-Level Data Representation</td>
<td></td>
<td>X</td>
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<tr>
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<tr>
<td>AR/Performance and Energy Efficiency</td>
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<td>AR/Heterogeneous Architectures</td>
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<td>X</td>
</tr>
<tr>
<td>AR/Quantum Architectures</td>
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Mostly as CS2013
CS Core: understood by the subcommittee AR

New KUs and topics CS202x
KUs/concepts must be CS Core

- Revised topics: advances in memory caching and energy consumption
  - AR/Digital Logic and Digital Systems
  - AR/Machine-Level Data Representation
  - AR/Assembly Level Machine Organization
  - AR/Memory Hierarchy
  - AR/Interfacing and Communication

- KUs/concepts that may be CS core
  - AR/Functional Organization
  - Integrate “Organization” into “Architecture”
KUs/concepts should KA Core

- Emerging AR topics, 10-years horizon
  - AR/Heterogeneous Architectures
    - In-Memory Processing (PIM)
    - Domain-specific architectures (e.g. Neural Network Processors)
  - KU AR/Quantum Architectures
    - "toolbox" covering introductory topics.
    - ACM SIGCSE 2022 TS BOF Session: Should Quantum Processor Design be Considered a Topic in Computer Architecture Education?
  - Accepted paper ACM SIGCSE TS 2023:
    - On the Design and Implementation of a Quantum Architectures Knowledge Unit for the CS Undergraduate Curriculum

- KA core KUs:
  - AR/Performance and Energy Efficiency
  - AR/Heterogeneous Architectures
  - AR/Quantum Architectures
Professional dispositions

- **Self-directed:**
  - students to become self-motivated to acquire complementary knowledge from systems technical documentation.

- **Proactive:**
  - appreciate that a computer system is a layered architecture that brings together programming, parallel and distributed computing, and computer architecture. Students need to be proactive and independent to navigate and integrate knowledge from different knowledge areas (transdisciplinarity).

- **Inventive:**
  - students should look beyond simple solutions to computer architecture design issues and leverage architecture-specific features when possible to improve their applications.

- **Professional:**
  - computer systems, particularly embedded sensors, can directly interface with the user's body (e.g., real-time glucose monitoring). Students should exercise discretion, behave ethically and appreciate user safety, security and privacy concerns.
Surveys

- Academic Survey
  - US - 212 respondents
  - Global - 191 respondents
- Industry Survey
  - 865 respondents
- Surveys, summaries posted on csed.acm.org
To what extent did CS2013 influence your program?

**US Academic Institutions**

- Answered: 200  
- Skipped: 13

- Not at all: 15.00% (30)
- To some extent: 62.50% (125)
- To a great extent: 22.50% (45)

**Global Academic Institutions**

- Answered: 160  
- Skipped: 31

- Not at all: 21.25% (34)
- To some extent: 58.33% (93)
- To a great extent: 20.63% (33)

**ANSWER CHOICES**

<table>
<thead>
<tr>
<th>Choice</th>
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Architecture and Organization KA

US Academic Institutions

<table>
<thead>
<tr>
<th>A LOT</th>
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<th>SLIGHTLY</th>
<th>NOT MUCH</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you benefit from this KA’s guidelines?</td>
<td>9.86%</td>
<td>19.72%</td>
<td>40.83%</td>
<td>9.15%</td>
<td>20.42%</td>
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<td>How much has this KA’s content changed since 2013?</td>
<td>4.41%</td>
<td>16.18%</td>
<td>40.44%</td>
<td>19.85%</td>
<td>19.12%</td>
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<tr>
<td>How relevant is this KA to CS today?</td>
<td>20.14%</td>
<td>40.29%</td>
<td>31.65%</td>
<td>2.16%</td>
<td>5.76%</td>
</tr>
</tbody>
</table>

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<tr>
<td>Did you benefit from this KA’s guidelines?</td>
<td>10.11%</td>
<td>22.47%</td>
<td>34.83%</td>
<td>13.48%</td>
<td>19.10%</td>
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<tr>
<td>How much has this KA’s content changed since 2013?</td>
<td>6.74%</td>
<td>34.83%</td>
<td>24.72%</td>
<td>15.73%</td>
<td>17.98%</td>
</tr>
<tr>
<td>How relevant is this KA to CS today?</td>
<td>17.98%</td>
<td>38.20%</td>
<td>31.46%</td>
<td>3.37%</td>
<td>8.99%</td>
</tr>
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</table>
How important is competency-based learning in the curriculum?

US Academic Institutions

There has recently been a move from knowledge-based to competency-based learning in computing, and recent curricular guidelines in other computing disciplines have emphasized competencies. Competency is defined as the synergy of knowledge, skills, and professional dispositions, where professional dispositions, such as persistence, collaborativeness, adaptability and self-directed learning, are demonstrated within the context of computing tasks. How important is competency-based learning in the curriculum?

Answered: 112  Skipped: 91

- Must include
- May include
- May not include
- Must not include
- No opinion

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Global Academic Institutions

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Computer Science Curricula 2013

Curriculum Guidelines for Undergraduate Degree Programs in Computer Science
December 23, 2013
The Joint Task Force on Computing Curricula Association for Computing Machinery (ACM) IEEE Computer Society

Description of Knowledge Units

AR/Quantum Architectures

Topics
- Principles
  - The Wave-Particle Duality Principle
  - The Uncertainty Principle in the Double-Slit Experiment
  - What is a Qubit? Superposition and Measurement. Protons as qubits.
- Axioms of QF*: Abelian groups, unitary evolution, the Heisenberg picture, etc.
- Single qubit operators.
- Two qubit gates and tensor products. Working with matrices.
- The No-Collapsing Theorem. The Quantum Teleportation protocol.

QED-C

- Algorithms
  - Simple quantum algorithms: Bernstein-Vazirani, Simon’s algorithm.
  - Implementing Deutsch-Josza with Mach-Zehnder Interferometers.
  - Quantum Factoring (Shor’s Algorithm)
  - Quantum Search (Grover’s Algorithm)

- Implementation aspects
  - The physical implementation of qubits (there are currently nine qubit modalities)
  - Classical control of a Quantum Processing Unit (GPU)
  - Error mitigation and control. NISQ and beyond.

- Emerging Applications
  - Post-quantum encryption
  - The Quantum Internet
  - Adiabatic Quantum Computation (AQC) and Quantum Annealing

https://cse.doe.net/
CS2023 Parallel and Distributed Computing (PDC KA)

October 2022 Overview and Status

Douglas Lea, SUNY Oswego, USA

https://csed.acm.org/parallel-and-distributed-computing/
PDC growing in diverse ways over the past 4 decades

<table>
<thead>
<tr>
<th>Category</th>
<th>Typical <strong>Execution</strong> agents</th>
<th>Typical <strong>Communication</strong> mechanisms</th>
<th>Typical <strong>Algorithmic</strong> domains</th>
<th>Typical <strong>Engineering</strong> goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multicore</td>
<td>threads</td>
<td>Shared memory, Atomics, locks</td>
<td>Resource management, data processing</td>
<td>throughput, latency, energy</td>
</tr>
<tr>
<td>Reactive</td>
<td>Handlers, threads</td>
<td>IO Channels</td>
<td>Services, real-time</td>
<td>latency</td>
</tr>
<tr>
<td>Data parallel</td>
<td>GPU, SIMD, accelerators, hybrid</td>
<td>Shared memory, messaging</td>
<td>Linear algebra, graphics, data analysis</td>
<td>throughput, energy</td>
</tr>
<tr>
<td>Cluster</td>
<td>Managed hosts</td>
<td>Sockets, Message channels</td>
<td>Simulation, data analysis</td>
<td>throughput</td>
</tr>
<tr>
<td>Cloud</td>
<td>Provisioned hosts</td>
<td>Service APIs</td>
<td>Web applications</td>
<td>scalability</td>
</tr>
<tr>
<td>Open Distributed</td>
<td>Autonomous hosts</td>
<td>Sockets, Data stores</td>
<td>Fault tolerant data stores and services</td>
<td>reliability</td>
</tr>
</tbody>
</table>
PDC CS Core Knowledge Unit

The big picture: “PDC from bits to bitcoin”
What every CS graduate must know or be able to do, along **four topic areas**

- Parallel program design and execution
  - Procedural, reactive, distributed, … decomposition and program control

- Communication
  - Shared memory and data stores, message channels and sockets

- Software Engineering
  - Safety, liveness, throughput, latency, security, energy, …

- Algorithms and Applications
  - Linear algebra, data analysis, resource management, …

For detailed in-progress snapshot, see [https://docs.google.com/document/d/1Z1m9tbCoRcqEbfocRPUlZrH2xz4BARGchA4WYu9V2E/edit?usp=sharing](https://docs.google.com/document/d/1Z1m9tbCoRcqEbfocRPUlZrH2xz4BARGchA4WYu9V2E/edit?usp=sharing)
Four PDC KA Knowledge Units

Each covers more depth of the four Core topic areas, but does not require equal depth across subtopics.

Accommodates and encourages multiple specialized courses, including for example:

- HPC using MPI focussing on scientific applications
- Heterogeneous parallelism focussing on linear algebra
- Multicore concurrency focusing on systems software and resource management
- Distributed programming focussing on shared data stores and commerce
Next Steps

- Calm down people who react saying that there’s too much X and not enough Y, for every X and Y! But still improve balance and coverage.
- Continue to develop narrative walkthrough of spec to clarify terms, usages, and practices that differ across subfields
- Provide more detailed sample course outlines
Computer Architecture Education in Brazil

Carlos Augusto Martins (PUC Minas)
Education and Curriculum Perspective in Brazil

Cristian Koliver (UFSC)
History (Brazil)

Data Processing (Technology)

Systems Analysis (BSc)

Computer Science (BSc)

Computer Engineering (BSc)

Information System (BSc)

DCN CES/MEC
Brazilian Computer Society and Computer and Informatics Courses

- Brazilian curriculum guidelines (Ministry of Education) for computing undergraduate courses were strongly influenced by the reference curriculum of the Brazilian Computer Society (SBC)
So Many Courses!

- New areas have emerged or expanded
  - *Lato sensu* postgraduate courses become new undergraduate courses
  - Data Science, Software Engineering
- How will young people preparing to enter university know the difference between them?
Panel Questions

ACM/IEEE-CS/AAAI
COMPUTER SCIENCE CURRICULA (CS2023)
PANEL WEAC - Workshop on Computer Architecture Education @WSCAD 2022
Panel Questions [Portuguese]

1. As unidades de conhecimento do currículo CS2023 nas áreas de arquitetura (AR) e processamento paralelo/distribuído (PDC) estão minimamente completas?

2. Como os painelistas entendem novas diretrizes curriculares baseadas em modelo de competências, considerando o contexto educacional brasileiro?

3. Existe hoje uma lacuna entre o conteúdo explorado e as necessidades do mercado de trabalho. Essa lacuna pode ser preenchida com novas diretrizes curriculares?

4. O Brasil tem um contexto social muito diferente de outros países (incluindo os EUA). Como podemos lidar com as diferenças de contexto e nível de aprendizado base dos noss(os) estudantes? Essas lacunas podem ser preenchidas através de currículos mais flexíveis (ex. baseado em competências, personalização)?
THANK YOU

Marcelo Pias
mpias@furg.br